UNIVERSITY OF
KWAZULU-NATAL

Energy Audit of the Howard College Campus of the University of KwaZulu-Natal

By

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Submitted in partial fulfilment of the academic requirements for the degree of Master of Science in Engineering, in the School of Electrical, Electronic and Computer Engineering, Howard College Campus, University of KwaZulu-Natal, Durban, South Africa

I hereby declare that all the material incorporated into this thesis is my own original and unaided work except where specific reference is made by name or in the form of a numbered reference. The work contained herein has not been submitted for a degree at any other University.

Signed: ____________________
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Date: 4 April 2005

ABSTRACT

Load growth projections on South Africa's electricity demand indicate that Eskom's spare capacity will be eroded by the year 2005. In the late 1960s South Africa experienced electricity shortages and Eskom embarked on a program to build large coal fired power stations, to ensure that South Africa would have sufficient electricity capacity to meet the envisaged high growth rate. With sanctions being imposed on South Africa, the demand was much less than predicted and in the late 1980s South Africa had an excess of generating capacity, which resulted in some power stations being mothballed. Due to the increased economic growth after the 1994 elections and Eskom's electrification drive, there has been an increase in demand and the excess capacity has diminished. From past experiences, the lead time to build a power station varies with the type of power station. For large fossil, nuclear and hydro plants, the lead time is in excess of six years. Gas fired stations can have a lead time of less than three years. An option to defer the building of new power stations to meet this expected shortfall in demand is Demand Side Management (DSM). Eskom has already begun initiating a DSM program to try and defer the expected demand shortfall.

From a university perspective there have been cutbacks in funding from government. For this reason tertiary institutions have been forced to review the way in which they manage their operating costs. A large tertiary institution spends a substantial portion of their facilities budget providing utility service to the campus. At most universities, 20 % or more of the annual utility budget is for electricity. In many facilities operations, tremendous potential exists to improve on energy efficiency and resource conservation and to reduce electricity costs. The management of energy tended not to feature very high on the list of priorities of tertiary institutions. Therefore targeting electricity for cost reductions in a campus environment makes sense. Additionally the historically low electricity price in South Africa, coupled with economic isolation meant that there is a proliferation of inefficient energy technologies present.

The University of KwaZulu-Natal campuses (Medical, Pietermaritzburg, Howard College and Edgewood) spend about R 8 million per year in electricity expenditure. This constitutes about 5.8 % of the annual operational costs for the abovementioned centres (excluding salaries and capital expenditure). Not only is energy consumption a significant cost to the university, but energy use at the university also contributes to the depletion of natural resources and environmental problems associated with energy production and processing.

The work presented in this thesis is the first step towards the establishment of what has become the formal energy management program at the University of KwaZulu-Natal. A comprehensive energy audit was conducted and metering of the mini substations was subsequently introduced. The readings from these meters, together with the results of the energy audit, are analysed. A successful case study involving energy efficient lighting technology implemented on the campus main library is also discussed. Energy savings of approximately R 220 000 per annum has been realised from the implementation of this case study. Conservative estimates to retrofit all the existing luminaires, with more modern efficient luminaires, show that the lighting system demand component can be reduced by approximately 600 kW. The audit has revealed loads that can be potentially shifted without adversely affecting regular campus activities. The air-conditioning load has been identified as an area where considerable savings can be attained.

The ability to conservatively reduce the base load will realise savings in excess of R 100 000 per annum (2002 costs) and merely requires an awareness campaign to be instituted at minimal cost. The specific objectives of the study are given in the table below:

Specific Objectives of the Study		Objective Achieved
1	To conduct an energy audit to identify major energy users on the campus	YES
2	To establish a database of historical energy consumption data for each building on the Howard College campus.	YES
3	To further investigate the larger users of energy and quantify their energy consumption, and identify trends, where possible.	YES
4	To make recommendations where possible, for savings to be made	YES
5	To implement a case study demonstrating that energy management is a viable option.	YES

As can be seen from the above table, all of the objectives were met. This analysis forms the basis of future efforts in the energy management program at the University of KwaZulu-Natal.

ACKNOWLEDGEMENTS

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List of Symbols and Abbreviations

Abbreviation	
BMS	Building Management System
CFL	Compact Fluorescent Lamps
DSM	Demand Side Management
ECOs	Energy Conservation Opportunities
Eskom	Largest South African Power Utility
HVAC	Heating, Ventilation, Air-Conditioning
kW	KiloWatt
kWh	Kilowatthour
MD	Maximum Demand
SHE Policy	Safety, Health and Environment Policy
TOU	Time-Of-Use
EM	Energy Management

Chapter 1

Problem Definition

1.1. Introduction

The rising cost of energy, heightened public concern about the environmental impacts of energy use, and the rapid liberalization of the power and energy industry throughout the world have combined to increase the relevance and importance of energy management and conservation in an increasingly technological driven world with diminishing energy resources.

This applies to tertiary institutions where, tremendous potential exists to reduce both electricity usage and costs. Tertiary institutions in South Africa rely on government subsidies to a very large extent for their operational budgets. With cutbacks in these subsidies, these institutions have now been forced to review their expenditure in all areas [1]. Although tertiary institutions spend a substantial portion of their facilities budget to provide utility services to the campus, the management of energy tends not to feature very high on their list of priorities. This is mainly due to the relatively low tariff cost of electricity in South Africa in comparison to the rest of the world. The perception is that the electricity tariff cost will continually remain low and therefore this is not a cause for concern. This is in fact not the case as the electricity costs have been kept artificially low and is due to rise sharply within the next few years [2]. Therefore targeting energy usage on campus for cost reductions makes sense.

The University of KwaZulu-Natal spends about R 8 million per year for payment of electricity expenses in the Medical, Pietermaritzburg, Howard College and Edgewood campuses [3]. This constitutes about 5.8 % of the annual operational costs for the University of KwaZulu-Natal (excluding salaries and capital expenditure) [4]. Not only is energy consumption a significant cost to the University, but energy use at the university also contributes to the depletion of natural resources and environmental problems associated with energy production.

Towards the end of 1997, a presentation was given to then University of Natal management team, by various University staff members, on innovative ways to implement cost savings at then University of Natal. One of the presentations suggested implementing an energy management study on the campus to identify, and then later exploit, possible energy savings. The University Principal at that time, Professor Gourley later approached the author of the presentation, Mr G Diana, and requested that an energy audit be conducted on the campus of the then University of Natal. This is the origin of this study.

1.2. What is an Energy Management Program?

It would be pertinent to define what Energy Management is and what constitutes an Energy Management Program. Although it can be argued that the definition is fairly standard, different practitioners place emphasis on different aspects in their programs. The intention is to ascertain what are the different aspects that an Energy Management Program comprises of.

Based on the Oxford definitions of the words "energy" and "manage", energy management may be defined as [5] "*the effective control of fuel and other resources that are used in the operation of machinery*".

Another generic term that is often used to describe the same concept is Demand Side Management (DSM). The American Department of Energy (DoE) defines DSM as the "*planning, implementation and monitoring of utility activities designed to encourage consumers to modify patterns of electric usage, including the timing and level of electricity demand. It refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load shape changes arising from the normal operation of the market place or from government-mandated energy efficiency standards. Demand side Management (DSM) covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.*" [6].

Fig 1.1 summarises the above definitions graphically.

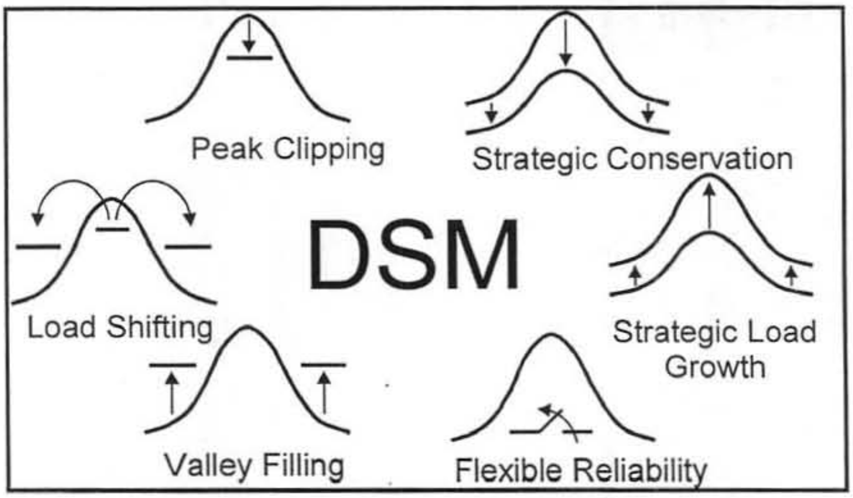


Fig 1.1: Demand Side Management Approaches

The DoE's definition of DSM implies that the above-mentioned measures are only taken in response to utility administered programs, whereas Calmeyer's [5] definition doesn't imply or state what the catalyst to this program should be. Monash [7] states, "*the term demand-side management encompasses the entire range of activities, whoever they may be initiated by, that include load management, strategic conservation, increased market share, and other behind-the-meter actions. Technically, load management is a subset of DSM, encompassing only the actions initiated by the utility or its customers as a result of incentives to accomplish peak clipping, valley filling and load shifting. However in common usage, DSM is often thought of as having a horizon extending over decades, whereas load management is thought of having a shorter horizon.*"

DSM programs are claimed [8] to improve relations with state regulatory commissions because energy savings defer the need to build new power plants. Deferral reduces pollution, and it generally is less expensive to improve energy efficiency than to build new power plants. His statement implies that DSM programs are driven by environmental concerns.

Energy management is also defined as the judicious and effective use of energy to maximise profits (minimise costs) and to enhance competitive positions [9]. In today's global market place, price competitiveness is forcing all businesses and institutions to investigate ways in which to reduce their overhead costs, of which the energy bill is a substantial contributor. This definition implies that cost saving is the prime driver.

DSM is also described [10] as a principle that embodies engineering, design, applications, utilization, and to some extent the operation and maintenance of electric power systems to provide for the optimal use of electrical energy. Optimal in this case refers to the design or modification of a system to use the minimum overall energy where the potential or real energy savings are justified on an economic or cost benefit basis. Optimisation also involves factors such as comfort, healthful working conditions, the practical aspects of productivity, aesthetic appeal and public relations.

DSM has advanced technologically to the point that equipment performance can be easily and accurately predicted [11]. The unpredictable aspect of DSM is human behaviour. An organization's energy-management program affects administrators, teachers, students, parents and support staff, and the program's success is contingent upon their support. A district must obtain the buy-in of everyone affected in order to control energy-management behaviour. People are the most critical factor in the success of DSM, and their presumed behaviour is an important component in projecting energy cost savings. Given the varied duration of payback on measures taken, a community or company must have a commitment that will endure changing boards, changing personnel, and changing energy services personnel. To be successful, this commitment must continue even if the originators of the project are no longer involved.

It can therefore be concluded that energy management encompasses the aspects shown in Fig 1.2.

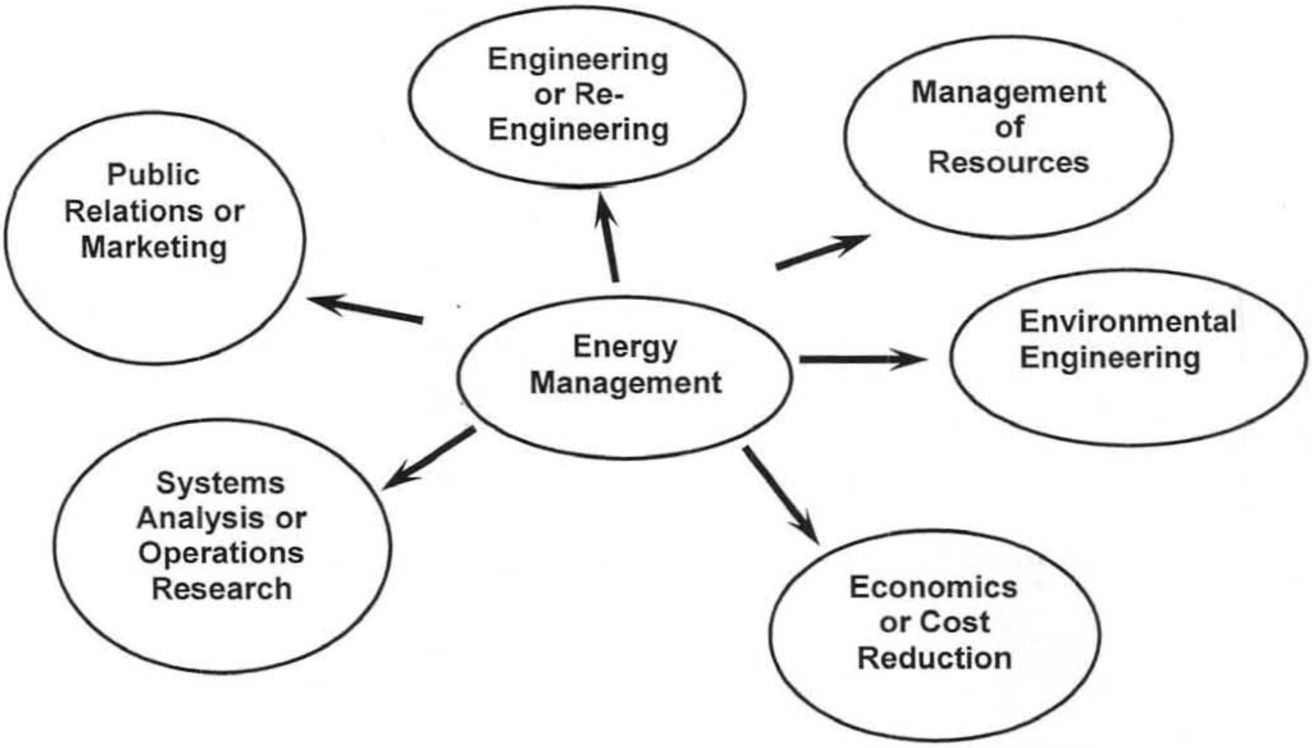


Fig 1.2: Important Aspects that needs to be covered in a Successful Energy Management Program

The aspects are all used to optimise energy consumption, to realise cost-savings to the end-user and to reduce the harmful effects of energy production, processing and utilisation on the environment. All the concepts shown above are of equal importance in ensuring the success of the program.

1.3. Problem Definition

In 1995 the University of KwaZulu-Natal management took the decision to outsource the maintenance of all its facilities. The maintenance contract was awarded to an external company called Facilities Management Group (FMG); part of FMG's mandate was Energy Management. Due to budget constraints on their part (there wasn't a specific budget allocated for Energy Management until November 1999), energy management pretty practice was limited to power factor correction at the main incomer and the trail of certain energy efficient luminaires in certain areas of the campus [12]. Therefore very little tangible energy management took place on the campus.

The initial survey conducted by the author at the beginning of the project, revealed that there was scant information available, at the University or the offices of FMG, on energy usage.

Beside available information on the electricity bill statement, there were no other records of electricity usage. FMG had been mandated to form an Energy Management committee. The efforts of this committee over a period of three years amounted to the following [12]:

- Reviewing maintenance procedures with a view to making them cost effective and proactive, instead of reactive.
- Endeavouring to utilise equipment of higher energy efficiency than present condition when installing refurbished/upgraded/new equipment.
- Improving reliability economically to minimise the downtime effect.
- Improving ambient lighting.
- Power Factor Correction.
- Periodically reviewing the electrical tariff.
- Upgrading and extension of thermal storage systems.
- Installation of a building management system (BMS).

Although these values were aspired to, a lack of funds and commitment from the University management, meant that no real advances were made. A prominent shortcoming of the effort by the Energy Management Committee was that due to the lack of sub-metering they were not able to qualify and quantify their efforts although there were definite savings made through some of their endeavours.

An additional problem was that the energy management committee largely comprised of expensive external consultants who were being paid for by the hour. Since there was no specific budget allocated for energy management exercises, principles of energy management were at best incorporated into new projects, and in most cases later thrown out due to budget constraints.

Although the university had mandated FMG to exercise energy management, there was no real commitment from the university management to this cause. There was no real responsibility or accountability for energy management. The issue of a lack of budget ensured that this lack of accountability continued.

There was also very little information available on some of the systems in place. Some of the contractors and consultants ensured that this culture continued so that the retention of their services would be ensured.

In order to have an effective energy management programme at the university the following prerequisites are necessary:

Ongoing commitment from ALL those at the university	Sources of finance
Ongoing commitment from university management	Measurement of performance.
Responsibility and accountability for energy conservation	Safety Health Environment (SHE) Policy
Mechanisms to identify wastage and energy conservation opportunities	Reward Mechanism

It was apparent that none of the prerequisites above were being met, prior to the start of this project. Consequently, to establish an energy management program required going through the entire process. A common flowchart used to conduct an energy management program is shown in Fig 1.3.

The scope of this thesis is up to and including step 5 of Fig 1.3. Steps 6 to 8 are future work. This flowchart will be explained in greater detail in Chapter 2.

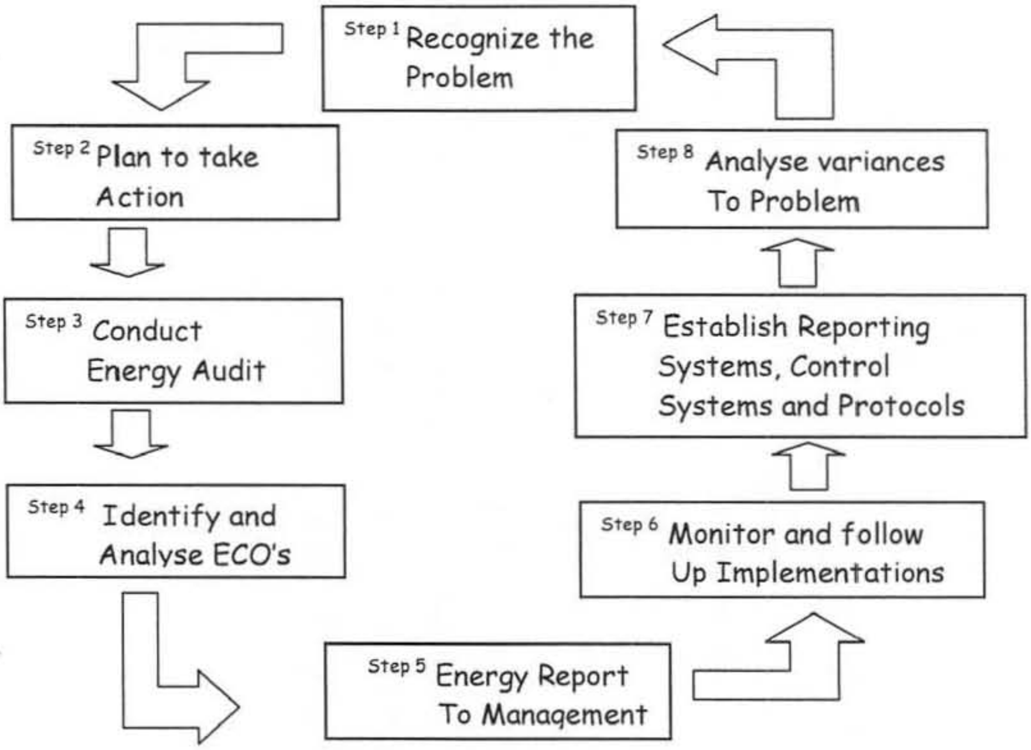


Fig 1.3: Flowchart Illustrating the Process followed in an Energy Management Program

1.4. The University of KwaZulu-Natal

Located in the province of KwaZulu-Natal, the University of KwaZulu-Natal consists of five separate campuses namely the Durban campus, the Westville campus, the Pietermaritzburg campus, the Medical School campus and the Edgewood campus. Pietermaritzburg is located in the centre of the scenic Natal Midlands, close to numerous nature reserves and parks, and is an hour's drive from Durban. Following initial investigations on the Durban, the Medical School and Pietermaritzburg campuses it was decided to focus only on the Durban campus (also known as the Howard College campus). The choice of the Durban campus was made because:

- There is only a single billing meter at the main incomer.
- Very close proximity to the Medical School campus.
- Building Management System already in place.
- Logistic reasons (the researcher was based at this campus).

1.5. Main Objectives

The main objective of this thesis is to establish a base for energy conservation opportunities to be realised. This will result in electricity cost savings at the University of KwaZulu-Natal.

The reason for establishing the specific objectives was to create an information base from which the energy management program could be established. Information on the energy usage patterns is vital to informing the way forward for any energy management program. Objectives 1 to 4 provide the information base required for this purpose. Objective 5 below will be used to demonstrate the accuracy of the energy saving projection models used by the researcher and the economic viability of energy efficiency projects.

1.5.1. Specific Objectives of the Study

1. To conduct an energy audit to identify major energy users on the campus.
2. To establish a database of historical energy consumption data for each building in the Durban campus.
3. To further investigate the larger users of energy and quantify their energy consumption, and identify trends, where possible.
4. To make recommendations where possible, for savings to be made.
5. To implement a case study demonstrating that energy management is a viable option.

Chapter 2

Literature Survey

2.1. The Origins and Evolution of Energy Management

Energy has long played a central role in the development and functioning of the world's economy. Reliance on energy will continue to grow as the world's population increases and standards of living and quality of life continue to improve. The trend towards increased mobility, urbanisation and an integrated global economy will further accelerate our energy use and dependence. This has particular relevance to South Africa whose population growth rate and accompanying demand on energy resources have a severe impact on the country's natural resources [13].

In 1994 the newly elected South African government committed Eskom to have a further 1 750 000 households electrified by the year 2000. Although by 2000 Eskom had exceeded this national electrification target, they have set themselves a further three year target of 600 000 new connections, giving more attention to rural areas [13]. With the domestic sector being the third largest consumer of total net energy and electricity in South Africa and growing all time (industry being the largest and commerce the second largest), it stands to reason that with a growth in the demand the impact on the cost of energy will be an increase of energy cost over a period of time. This is now evident with an increasingly "peaky" morning and evening peak, as shown in Fig 2.1. [14]. The evening peaks tend to dominate and this is highlighted by the red circles in Fig 2.1.

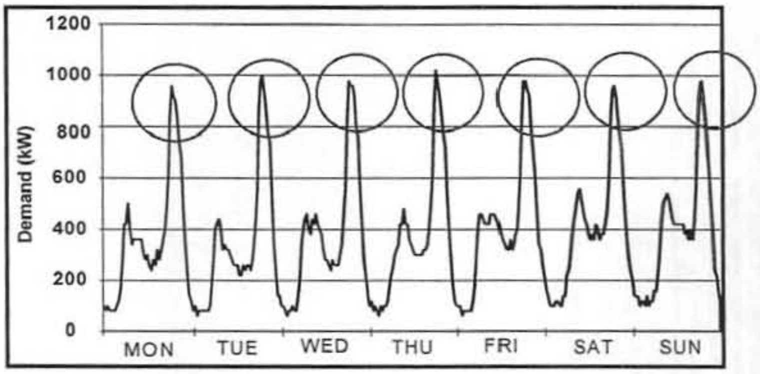


Fig 2.1: Load Profile Indicating Morning and Evening Peaks

Key methods of stimulating energy conservation amongst users are legislation and market signals through energy prices [5]. Presently South Africa has one of the lowest electricity prices in the world [19]. Whilst cheap energy provides a competitive advantage to South Africa's industry and consumers, especially the major foreign exchange earners, concern exists that the consumption of energy has harmful environmental and health effects. These costs are not included in the price of energy. Although researchers in South Africa have identified significant energy efficiency opportunities with typical conservative estimates of between 10% and 20% of current consumption [15], barriers towards the adoption of efficiency measures still exist and include [5]:

- Inappropriate economic and pricing signals.
- Lack of awareness, information and skills.
- Lack of access to efficient technologies.
- Demand for a high return on the investment of capital.
- High cost of investment capital.

To overcome these barriers, the South African government has set out the following actions for energy management in the 1998 White Paper on Energy Policy [16]:

- The creation of consciousness regarding energy efficiency.
- The establishment of energy efficiency norms and standards for commercial buildings.
- The facilitation and the performance of audits, demonstrations, information dissemination, sectoral analyses and training programmes.
- The establishment of energy efficiency standards for industrial equipment.

From the above policy actions, it is apparent that the extent of governmental involvement is aimed at creating an environment in which energy management can take place although the policy does not make provision for legislature aimed at forcing companies to adopt energy management programmes. Although there are no legislative measures being taken standards are being developed to encourage energy management programmes.

Eskom has recently started to try and stimulate energy management by instituting a Demand Side Management (DSM) Programme. The findings of a DSM study by Eskom show that if South African industry could, through the more efficient use of electricity, reduce its industrial consumption by 1170 MW and, likewise, the domestic sector by 1651 MW, energy efficiency could be attained at lifecycle costs that are lower than those involved in the construction of an additional power station [17]. This would result in capital expenditure saving to Eskom (deferring the need for new supplies) and also resulting in savings for the customer. There are also standards being developed by the South African Department of Minerals and Energy (DME). One such standard is the South African Energy and Demand Efficiency Standard (SAEDES) [18].

The South African Department of Minerals and Energy (DME) and others are currently developing SAEDES for new and existing commercial buildings. This standard shall be used to encourage good design, innovation and use of renewable energy resources. The standards objectives include technical, economic, and social considerations. Some of the specific considerations are economic development, human comfort, employment, education, capital and operating cost reduction. SAEDES' purpose is "to provide continued economic development and human well being through improved energy effectiveness in the non-residential building sector." The goal is "the assurance of human comfort; capital and operating cost savings; and the provision of environmental benefits to the people of South Africa and throughout the world." The environmental impact of industries around the world, particularly the energy industry, has come under tremendous scrutiny in the last decade [18].

2.2. Environmental Concerns

Reliance on fossil fuel is not the only concern and twentieth century human activities have added 925 billion tons of carbon dioxide (CO_2) to the atmosphere [20], which together with other greenhouse gases (GHG) such as methane (CH_4) and nitrous oxide (N_20) are responsible for global climate change. Although it is difficult to connect any single weather event to global climate change, the past few years have been marked by a worldwide pattern of unusually severe weather, such as floods and droughts [20].

The efforts to develop a global climate change agreement culminated in the Kyoto Protocol. The Kyoto Protocol focussed on approximately 168 industrialised countries (also known as Annex B countries) and set legally binding emission reductions (5.2 % below 1990 levels on average) for the countries that ratify the Protocol [20].

When the current emissions of developing countries are added to those of industrialized countries covered by the Protocol, the global total is projected at some 30% above the 1990 level by 2010 [21]. This means that developing countries also need to get their house in order and join the issue of climate change. It also means that future emission reduction targets will become increasingly strict and demanding.

2.2.1. Overview of the South African Environmental Position

South Africa as a developing economy is particularly vulnerable to the predicted climate change impacts, and is one of the top twenty greenhouse gas emitters in the world [22]. The South African government responded by signing the United Nations Framework Convention on Climate Change (UNFCCC) in 1993 and developed a proposed policy on global environment change. In the events leading up to Kyoto, South Africa's position was described as being the most ill prepared country in the world [22]. South Africa narrowly avoided having only observer status at the Kyoto conference by being the last country that officially ratified the FCCC in August 1997 [22].

Approximately 75% of South Africa's primary energy comes from indigenous coal. Another 10% comes from imported crude oil. Coal is the primary fuel produced and consumed in this country. Eskom, the world's fifth largest vertically integrated electric utility and has a nominal generating capacity of 39 154 MW from 20 power stations, with a system peak demand of approximately 32 000 MW. Two thirds of the national power capacity is concentrated in just 10 base load coal-fired power stations. The overall plant portfolio is made up of [68]: 34 882 MW coal fired, 600 MW hydroelectric, 1930 MW nuclear, 1400 MW pumped storage, and 342 MW gas turbine (oil fired). South Africa's population is approximately 42 million; 70% of which are grid connected, while 30% are off-grid.

South Africa has the largest potential for emission reductions on the African continent and is a very attractive candidate for emission reduction projects. Every kilowatt-hour of electricity saved means one less kilogram of carbon dioxide released into the atmosphere – therefore the environment will only benefit through energy management programs and the efficient use of energy [23]. It is obvious that the implementation of energy management programs, besides curbing energy wastage, also provides some substantial environmental benefits. Energy management programs also defer the need to build new power plants. Deferral reduces pollution, and it is generally less expensive to improve energy efficiency than to build new power plants [24]. Fossil-fuels, such as coal, petroleum and natural gas are also depletable energy resources.

2.3. International Energy Management Measures

There are, quite literally, thousands of institutions working to improve energy efficiency worldwide, including government agencies, intergovernmental organizations, non-governmental organizations, international financial institutions, and private firms [25].

The World Energy Efficiency Association (WEEA) is one such organization that was founded in June 1993 as a private, non-profit organization composed of developed and developing country institutions and individuals charged with increasing energy efficiency.

WEEA grew out of a 1992 initiative of the Atlantic Council of the United States which brought together a diverse group of over ninety world energy experts to study how to improve the effectiveness of energy technology cooperation, transfer efforts and programs. The group included significant representation from developing countries, Eastern and Central Europe and the former Soviet Union, and a broad cross-section of public and private institutions.

WEEA was established to facilitate communications among these institutions with an interest in energy efficiency. WEEA works closely with a network of hundreds of institutions worldwide to [25]: (1) to assist developing countries in accessing information on energy efficiency; (2) serve as a clearinghouse for information on energy efficiency programs, technologies and measures; (3) disseminate this information worldwide; and (4) publicize international cooperation efforts in energy efficiency.

The thrust of a large number of energy management efforts in developed countries is driven by legislation. This legislation is in response to the Kyoto protocol. The reasoning is that reducing the growth in energy consumption in different sectors – and in the long term reducing the level of energy consumption – must be a central element in all strategies to reduce the emissions of greenhouse gases from the energy sector. Actions on the supply side cannot alone do the job if CO_2 emission reductions of 50 % or more are achieved, which will be necessary in the next 20-30 years [26]. The efforts of these developed countries are very well documented.

2.4. Energy Management Efforts in South Africa

As more and more South African companies become integrated into the global economy and they will need to increase their competitive edge, some are turning to energy management as a viable option to reduce their overheads [27].

As briefly mentioned in section 2.2, Eskom has started a DSM Program. While Eskom formally recognised DSM in 1992, the first DSM plan was only produced in 1994. In this plan, the role of DSM was established and a wide range of DSM opportunities and alternatives available to Eskom were identified.

The South African government recognises the importance and potential of energy efficiency, and commits itself to promoting the efficient use of energy in all demand sectors. It also commits itself to investigating the establishment of 'appropriate institutional infrastructure and capacity for the implementation of energy efficiency strategies' [16].

Since Eskom already has the necessary expertise, skills and strategic positioning to be an effective vehicle for the implementation of these initiatives, Eskom DSM has been selected as the guardian of DSM. Government and the National Electricity Regulator (NER) have made available fund to implement DSM measures in South Africa [14].

The three focus areas of DSM are the:

- Commercial Sector.
- Industrial Sector.
- Residential Sector.

The aim of Eskom DSM is to provide a profitable investment opportunity to plant owners by identifying areas where electricity-usage can be optimised and better managed through the appropriate use and sizing of energy-efficient lighting, the upgrade of pumps, motors and compressed air systems, and HVAC systems.

The capital cost of this investment opportunity will be funded by Eskom's DSM budget, with a portion of the costs being paid back through the savings realised by the DSM intervention. It must be pointed out that this is not a repayment of a loan and the payback is only to offset the grant to DSM from the NER in the following years. The potential benefits to the client and Eskom are [14]:

- To reduce demand during peak times and therefore delay the supply of infrastructure capital investment.
- To improve the value of electricity service to customers by reducing energy costs - customers can choose from a range of energy efficient options and benefits financially.
- To conserve the environment by reducing emissions and water consumption at power stations.
- To support the macro-economic development of economies through job-creation and improved productivity.

The DSM initiative seeks to support the ESKOM Corporate Directive by means of encouraging strategic partnerships and joint ventures and assistance in establishing Energy Services Companies (ESCO's). These ESCOs will provide energy efficiency or load reduction services to customers that own or operate facilities in South Africa. An example of the process is shown in Fig 2.2.

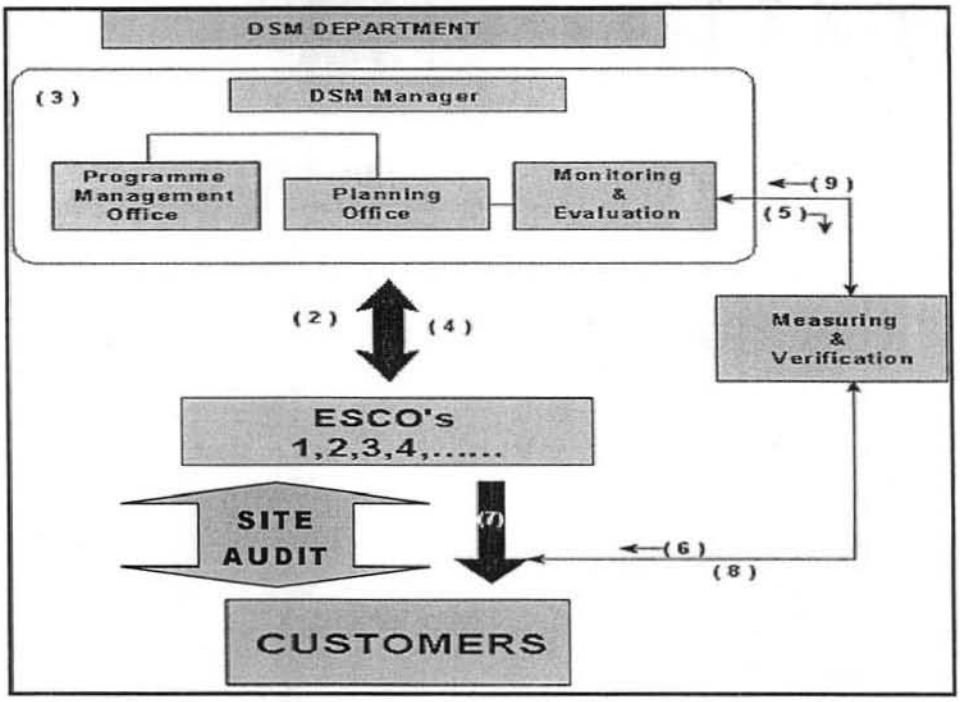


Fig 2.2: Eskom DSM Course of action

A recent highly successful program to stimulate energy efficiency on the lighting side has been the BONESA Project. Eskom and the Global Environment Facility funded the BONESA project [28]. The program was the extension of the Efficient Lighting Initiative (ELI). The BONESA project was a three-year, R63 million programme aimed at transforming the local market to make use of energy-efficient lighting technologies [28].

The Global Environmental Facility's main concern is to reduce greenhouse gas emissions from South Africa's coal-fired electricity industry by stimulating sustainable markets for energy-efficient products. In turn, Eskom aims to benefit by reducing evening peak electricity demand, of which a substantial portion is residential lighting. While the morning peak has a longer duration than the very short but high evening peak, it has a much smaller coincidence with residential load than in the evening [28].

Eskom, through Industrelek, is promoting the reduction of industrial consumer's energy bills through the utilisation of energy-efficient equipment and off peak lower-priced electricity. Other initiatives by Eskom include Eskom's curtailment agreement, which goes under the name of the Virtual Power Station (VPS). This initiative is a pilot project that involves large customers in a curtailment pricing agreement. Another initiative that Eskom has been involved in is the Coordinated Municipal Ripple Control (COMRICON) Project. This project involves shedding the hot water load of residential customers during the morning and afternoon peak [14].

One independent program that has been initiated on the demand side is the Green Buildings for Africa programme. The vision of the programme is to implement a commercially and environmentally responsible programme for property owners, tenants and occupants of properties, committed to the following principles in building design, maintenance and management [29]:

- Efficient use of energy and water.
- Minimising the global effects of facility use on non-renewable resources.
- Preserving and enhancing the local environment.
- Promoting higher standards of indoor environmental comfort and health.

2.5. Energy Management at South African Tertiary Institutions

At present, very few South African tertiary institutions have established energy management programs and those institutions that do have programmes have created them for the purpose of cost management or academic research as illustrated in Fig 2.3. With the rationalisation of government and sponsor funding, concern for the environment, increasing energy prices and possible government legislation, institutions have begun to pursue resource cost management, and in particular the cost of electrical energy [5].

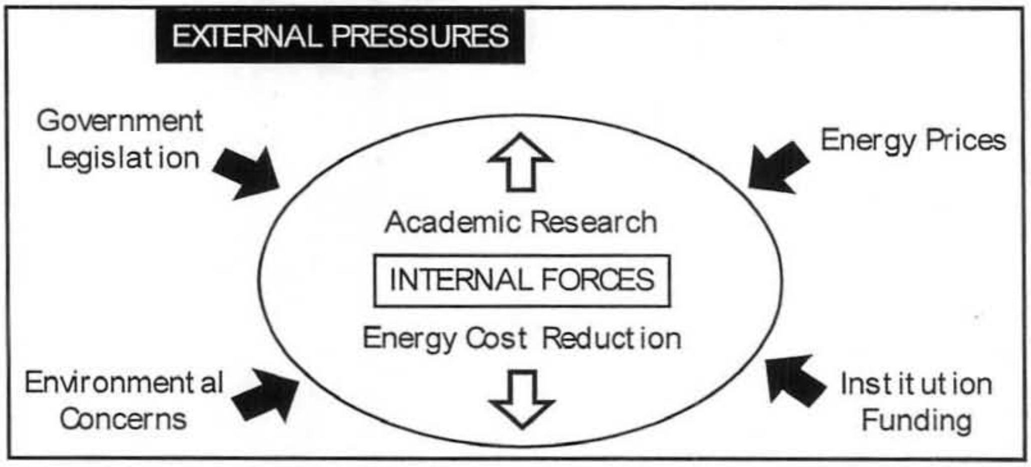


Fig. 2.3: Energy Management Pressures and Forces acting on an Academic Institution

Reasons for South African institutions failing to implement an energy management programme include:

- Lack of useful data on energy use.
- Limited access to investment capital for energy efficiency improvement.
- Lack of in-house expertise.
- Lack of awareness of the benefits of an energy management programme.
- Lack of portfolios dedicated towards energy.
- Lack of an awareness of the energy costs to the institution.
- Very few incentives for personnel to drive the programme.
- No legislative pressures from Government.

The institutions that do have established programmes have been able to harness or combine the expertise and research capabilities of their engineering departments (traditionally electrical and mechanical engineering) with the facilities management departments of their institutions. This union is brought about by the necessity of academics to experiment with their solutions and following this approach allows for the facilities of the institutions to be used as a site-wide energy management laboratory [5].

Some South African academic institutions research energy management at academic institutions primarily as a cost saving measure to the academic institution. The researchers then negotiate a percentage of the savings to sustain their research programs. As such it is pertinent to analyse the important themes in each of these regions [30].

The University of Pretoria has an advanced energy management programme. The energy management programme, at the University of Pretoria, was started during 1995 by Professor Johan Delport, with the installation of a campus-wide energy measurement system [30]. At that stage, the purpose of the system was to create an energy management laboratory that would be able to reinforce the energy management training received by students.

No real energy management programme was adopted, although many activities and projects were completed in an ad hoc basis. These projects were undertaken as and when time allowed the energy researchers to get involved and did succeed in not only providing energy cost saving, but created some awareness too. The management at the University did not drive the projects, as energy did not feature on the list of concerns of the University administration.

In March 1998 a comprehensive energy policy and strategy was adopted to give structure to the energy management programme on campus. The mission statement of the energy programme is to manage the energy resources of the University of Pretoria to ensure maximum benefit to the university community with the minimum energy consumption and cost [5].

This mission statement is achieved through 6 areas-of-activity. The six areas ensure that no single element is ignored or overlooked. The six areas are [5]:

- Energy Measurement and Control.
- Energy Economics.
- Energy Consumption Benchmarking.
- Energy Education.
- Product Supply and Maintenance Contracts.
- Energy Marketing and Awareness.

Energy management at this institution is now not solely performed for academic pursuit anymore but is also expected to streamline the expenditure of the University.

Other institutions that have started to address energy management on campus are the Potchefstroom University for Christian Higher Education [31], Rhodes University [32], University of Cape Town [33], Cape Technikon [34] and Technikon Northern Gauteng [35]. Although their programmes are at different stages of progress, the programmes are aimed primarily at the areas of load diagnosis followed by load management through direct control of energy equipment. Rhodes University has adopted an energy management programme purely as a method to cut down on costs [32]. This differs from all other institutions that are tackling this aspect from a research point of view.

2.5.1. esATI Energy Management Group

Very early on in this project it was realised that procuring funds for energy management was going to be a difficult task. This was mainly due to the fact that the University management had limited financial resources and did not see energy management as a priority. As a result the University of KwaZulu-Natal, in conjunction with three other tertiary institutions in KwaZulu-Natal, got together and formed the Eastern Seaboard Association of Tertiary Institutions (esATI) Energy Management Project [36].

The project was initiated in 1998. The Eastern Seaboard Association of Tertiary Institutions (esATI) Energy Management Project is a regional venture aimed at conducting research on using energy in the most cost-effective way [36]. The four member institutions where this research is currently taking place are the University of KwaZulu-Natal, University of Zululand, Durban Institute of Technology and the Mangosuthu Technikon. The sectors of the institutions involved in the project are academic staff and students from relevant disciplines (mainly electrical engineering); those who manage and operate electricity-consuming systems in the institutions; and the finance departments, which will need to assess the effects of the project in terms of the improved operations.

All the member institutions had submitted a combined funding application to The Human Resources in Industry Program (THRIP) and the funding was approved in 2000. The project proceeded for execution during 2000/2001 by successfully having the regional Energy Monitoring System installed. The system allows researchers participating in the project to access power load data via the Internet. Data acquisition is the cornerstone of any energy management programme [36].

The esATI Energy Management Project has two objectives [36]:

- To ensure that energy is used in the most cost-effective way on campus.
- To provide opportunities for students and staff to work on applied research projects that have specific benefits for the students, the staff and the institutions.

Benefits of the project include [36]:

- Substantial energy benchmark improvements.
- The creation of research opportunities at the level of MSc and MTech degrees in the region.
- Generation of funding for member institutions.
- Creation of a regional research project of real academic and applied value, drawing on the skills and interests of Technikons and Universities alike.

2.6. Energy Management at International Academic Institutions

It is impossible to present all the programs that are being carried out around the world [37]. Since the mid 90s an increasing number of university campuses have shown interest in Energy and Environmental Management issues. In European countries, action in this field has generally arisen from local initiatives; however, in a few countries, a more systematic assessment, including a series of complete energy audits, has been made in partnership with the national energy and environment agencies. In other countries around the world, including the USA, both situations can be found. Although most initiatives are to be found in the northern hemisphere, a growing number of institutions in the Southern hemisphere, such as in Australia and South Africa, are starting to also implement programs.

2.6.1. The Talloires Declaration: University Presidents for a Sustainable Future

About 260 Higher Education institutions in more than 40 countries have signed the Talloires Declaration [38]. It was voted in a meeting of the University Presidents for a sustainable future, in October 1990, in the French town of Talloires. It is probably the oldest initiative in this area and the related topics are not systematically recognised as a key priority.

There are ten goals that are set out for members to aspire to. The two that are most pertinent to this thesis are [38]:

- Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and responsible citizens.
- Set an example of environmental responsibility by establishing programs of resource conservation, recycling, and waste reduction at the universities.

Some of the Universities or Higher Education (HE) institutions that have or are starting to implement energy management programs are doing so due to the Talloires Declaration, whilst others are doing just because it makes plain good sense. Every institution of higher education spends a substantial portion of its facilities budget providing utility service to the campus. The challenge that facilities managers face is minimizing these costs so that adequate funds are available to achieve the institution's academic mission [39].

There are different concerns driving different energy management programmes in different parts of the world. In the EU for instance, environmental concerns are the prime drivers for implementing energy management programs at academic institutions. In the US, it is a combination of both cost saving to the academic institution as well as environmental considerations, although the weight of each concern will also vary from state to state.

2.6.2. The Ecocampus

In March 1995, the University of Bordeaux (France) hosted the "EUE-95" workshop. The Energy-University-Environment (EUE) Consortium recognizes that the management of natural resources at University campuses and research laboratories is based on a laissez-faire policy and this approach is undesirable for the following reasons [40]:

- The financial cost of energy increases, as more electronic equipment is added to laboratories and offices.
- The environmental degradation associated with power production for the operation of heating, cooling and lighting equipment to support teaching and research activities have also increased with a growth in energy consumption.
- The need for new research and development programs are not being addressed, due in part to artificially low energy prices and a lack of public awareness about the uncertainty of future energy supplies.
- Students are not receiving the best training because of limited texts and poor examples in campus buildings.

According to the EUE, the following barriers need to be removed before energy management programmes can be implemented at Universities:

- The lack of social concern for reducing energy use.
- A lack of priority for energy and environmental matters.
- Insufficient or inadequate capital funds.
- Inappropriate financial mechanisms that are able to capture savings in accounts that can be used to finance additional conservation investments.
- In countries in economic transition, other difficulties also appear:
    - Fuzzy relations between sustainable development principles, economic restraints and energy or environmental policies.
    - Divergent economy policy goals such as rapid growth and dwindling resources.
    - Inadequate and ineffective privatisation of state property.

2.6.3. Energy Management at US Tertiary Institutions

The Association of Higher Education Facilities Officers, in the United States of America, published an energy management workbook in 1994 [41]. The purpose of the workbook is to meet the needs of those institutions wanting to eliminate energy wastage on campus and reduce unit costs but lack the resources to implement the energy conservation projects that would increase the efficiency or address unit costs. The workbook focuses on a broad base of energy resources and includes electricity, coal, steam and natural gas. The book names five premises that an energy management program should be based on. They are [41]:

- There is no single approach that would fit any two campuses exactly. Each campus is unique and the program should be planned or managed as such.
- Key personnel such as management, maintenance personnel and tenants need to be involved in developing any plan if that plan is to be undertaken or implemented. By involving these personnel, you also get then to buy into the process, which greatly increases the chances of success.
- No one understands or knows the campus better than the campus personnel. The technical personnel can provide invaluable information with respect to the design and support functions of the energy networks whereas academic personnel and students have exposure to the end-use of energy.
- Energy management is a subset of facilities management and the two cannot be separated. Investing in energy management has a knock on effect on other parts of the facilities operation thereby improving total efficiency of the plant operations.
- The final premise is that resources for the reduction of energy consumption are available through a combination of internal and external funding resources. Internally, energy cost can be apportioned to specific processes as a recurring liability that must be budgeted for and proper external financing will allow the capital investment necessary to release funds through a process of reduced energy costs. These released funds can be used to support the academic teaching process.

These five premises indicate the important aspects, from the point of view of the Association of Higher Education Facilities Officers, of an energy management program.

Calmeyer [5] says that although seemingly well structured and very useful, the workbook itself is not a complete solution because it fails to adequately address a few key issues such as:

- A broad base of energy sources are considered, which may divert the focus from that resource which generates the highest cost and deserves the most attention.
- Energy tariff structures are not explained or dealt with and this is usually the starting point of any cost driven campaign.
- Very little attention is paid to establishing a relationship with the energy suppliers.

- No emphasis is placed on feedback with which to create a closed loop energy management program.
- Energy conservation (including efficiency) is considered as the only DSM activity that should be pursued by the institutions themselves.
- Consequently, it is felt that the utility should initiate the other DSM activities as only they can benefit from it.
- Energy awareness is considered as a secondary activity to the other elements of the programme and no structured approach is attached towards this activity.

2.7. Case Studies

Eto [42] stated that existing work tends to take the form of case studies, from which it can be difficult to generalize due to climatic variations. The energy management workbook also states "there is no single approach that would fit any two campuses exactly". Each campus is unique and the programme should be planned and managed as such. This section reviews energy management programs at some specific institutions. Note that this is by no means an exhaustive analysis of all energy management programs that are in existence at all academic institutions. Instead, some institutions have been selected that have similar climatic conditions and load makeup as the University of KwaZulu-Natal does. Therefore it is the intention to analyse a few tertiary institutions as case studies and find the common thread(s) that ensure success. This can then be incorporated into the Energy Management Program at the University of KwaZulu-Natal. This will give an indication of the successful measure and the not so successful measures taken by these academic institutions.

It would be pertinent to briefly introduce the University of KwaZulu-Natal as a test case now. The University of KwaZulu-Natal is situated in Durban, Kwazulu Natal. Durban is famed for its mild, sunny winter climate, subtropical climate with sunshine for at least 320 days a year. Temperatures range from 16°C and 25°C during the winter months of June, July and August. Summer temperatures can reach 32°C with relatively high humidity during the hot season [43].

Historically, the demand in the Durban centres peaks at the height of summer, which implies that air-conditioning is the main load contributor. Air-conditioning is required virtually all through the year and this is not surprising considering the climatic conditions of Durban. There are no heating requirements on this campus. The main incomer has a peak capacity of 6 MVA and the air-conditioning system's peak capacity accounts for 3.27 MW or 54.5 % of the capacity.

Therefore this background study will concentrate on academic institutions whose climate conditions are similar and whose main electrical load is air-conditioning.

2.7.1. University of Missouri-Columbia

The University of Missouri-Columbia (MU) has aggressively pursued energy conservation projects to reduce electricity usage and costs. In just the last five years, MU's program has saved over $2.7 million and reduced electric use by more than 15 %. MU's energy conservation program includes the following elements [39]:

- Establishing energy policies.
- Establishing and maintaining energy standards.
- Reviewing new construction and renovation design documents for compliance to energy standards and policies.
- Installing meters so that meaningful measurements can be used to manage campus energy use.
- Retrofitting existing lighting systems with energy-efficient systems where economically-justified. (Evidence of MU's success in this effort was earning the distinguished EPA Green Lights Partner of the Year Award in the university category in March 1995.).
- Retrofitting existing building temperature control systems with energy-efficient direct digital control systems.
- Upgrading and centralizing chilled water systems to energy-efficient systems.

MU's approach shows that a well-planned energy conservation strategy is important for long-term reductions in the campus energy bill.

There is also a 50-megawatt cogeneration plant producing economical steam and electricity for the campus. Cogeneration involves producing electricity as a by-product of supplying steam for heating, cooling, domestic hot water, and other process requirements. At MU, this by-product electricity meets about 35 % of campus electric needs. To supply the remaining 65 % of electricity needs, MU has two choices: 1) purchase the electricity, or 2) generate the additional electricity with the same turbine generators needed for cogeneration and then use "condensers" to condense the steam not required by the campus. MU has chosen to generate the additional electricity because the cost to generate power was lower than the cost to purchase it [39].

2.7.2. University of Brown

The "University of Brown Is Green" [44] initiative in 1990 to facilitate the conservation of resources, waste reduction strategies, and increased awareness of environmental issues on campus. All departments and individuals at the University contribute to the efforts of the program. Students conduct research on potential conservation strategies through Environmental Studies courses, internships, and the Brown Environmental Action Network (BEAN) student group.

Some of the measures taken to conserve electricity include [44]:

- Lighting Efficiency Upgrades.
- Motor Replacement Program.
- Metering.

On the Building energy systems side measures include:

- Renovation and New Construction: Including monitoring equipment on all new constructions or on renovations where possible.
- Heating and Cooling: Upgrades to mechanical systems in building to use Variable-Air-Volume, Variable-Frequency-Drives, and Direct Digital Control systems to monitor energy usage and reduce consumption levels.
- Chlorofluorocarbon (CFC) Phaseout : Management measures include the capture and reuse of purged refrigerants in appliances and HVAC systems. Ongoing research will determine appropriate measures for retrofitting or replacing existing equipment and develop specifications for new equipment to comply with regulations.

As part of their Green Programme, Brown is also looking onto Water Conservation. Some of the measures taken include:

- Low-flow Showerheads and Toilets: The heads reduce flows from an original 3.5 gallons per minute to approximately 2 gallons per minute, average. The original estimated savings from the project was 5.6 million gallons per year. A recent follow up study indicated user satisfaction is high and savings are higher than originally estimated A retrofit project in 1993 of 190 fixtures was completed in all athletic facility buildings. A newer showerhead was used in these installations that avoids some of the problems of clogging and "cold aeration" associated with earlier types of showerheads.
- Process Cooling: Improved water management in laboratory mechanical systems.
- Campus Water Audit.

Other measures of this program included promoting recycling and promoting the purchasing of energy efficient equipment and recyclable equipment, where applicable.

2.7.3. Stanford University

Stanford's Energy Management and Control System (EM&CS) is operated and maintained by Stanford's Energy Management Group. The Group is responsible for promoting, facilitating, and documenting energy conservation on campus. In addition to the EM&CS, functions include public awareness program development; funding and technical support for energy retrofit projects, utility demand management, and utility billing for Stanford provided utility service [45].

Stanford's EM&CS is a process control system used for control and monitoring of the Central Energy Facility Steam and Chilled Water Plants, monitoring of the Cogeneration plant, utility service entrance consumption and demand metering, utility demand management, central HVAC system control for Stanford's 80 largest buildings, monitoring of life safety systems, and local process control where needed. All system control logic development and programming, including new construction, is performed in-house [45].

An Ice Plant builds and stores ice at night to provide campus air conditioning the following day. This concept allows Stanford to take advantage of inexpensive off-peak electrical rates, and avoid expensive peak energy charges and electrical demand charges. Thermal capacity of 100 000 ton-hours of ice can be stored. This is the equivalent of 100 000 window air conditioners operating for 1 hour [45].

- This is the third largest ice storage facility in the world.
- The Ice Plant is 100% computer controlled and operated remotely. The plant is inspected once every eight hours.
- Stanford's current peak electrical demand is 25 MW.
- Ice storage technology saves Stanford about 8 MW of peak electrical demand and 5 MW of average summer daytime load over a conventional cooling system. This translates to annualised savings of about $500,000.

Stanford also has an Energy Retrofit Program (ERP) that has been established to reduce the overall energy costs on the Stanford University campus by improving building level energy efficiency. Funds are set aside each year to implement the most cost effective retrofit projects. Projects are ranked and funded on a simple payback basis and must have a better than five year payback. A typical energy retrofit project will improve energy efficiency and reduce building energy costs in addition to reducing utility demand, improving occupant comfort, and decreasing maintenance costs [45].

2.7.4. Murdoch University

Murdoch University, in Australia, started energy management in the early 1980's, by changing the electricity tariff to a time-based tariff. This new tariff did save the University money but was open to large penalty payments due to uncontrollable peak loads during the high tariff day period. To overcome this, in 1986 the Facilities Management installed a Central Monitoring and Control System to monitor and control the maximum demand of electricity consumed by the University [46].

Initially the demand was limited by means of turning equipment off for short periods of time, but as time progressed and more equipment was controlled and the capabilities of the system were mastered it was found that by altering parameters the same energy use could be achieved [46].

In the early 1990's the HVAC capability had to be upgraded and the University added an Ice Storage system that utilised cheap off peak electricity to generate ice at night. This allowed Murdoch to supplement the chiller capacity on extreme temperature days with the full flexibility to use only ice on the mildest of temperature days, providing effective energy management by using the lower tariff to generating storable energy. This procedure is still used to generate ice and assist the University to limit its maximum demand [46].

2.7.5. The University of Vermont

The University of Vermont, through its energy policy, has committed to conserving energy – with the goal of reducing the campus energy consumption over the next five years by 20% compared to the consumption during 1989-1990. This is very similar to the agreement made in the Kyoto Protocol. This policy was formulated from the ideas and suggestions of the members of the University community and the University's Energy Management Council. The policy aims to accomplish these goals by addressing the following aspects of Vermont's operation [47].

- Improving building operations through scheduling and increased efficiencies.
- Optimising the energy usage of the central heating plant.
- Incorporate energy management measures in new structures.
- Improve interior lighting and use natural light where possible.
- Reducing energy and maintenance costs on the Mechanical Cooling equipment.

- Reduce water usage.
- Reduce Solid Waste through recycling.
- Implement Green Transportation where possible.

The intent of this policy is to insure that energy efficiency is improved through education, research and development; and, that knowledge gained be shared. The Energy Management Council encourages and endorses the use of new, sound energy management techniques and equipment and continues to provide guidance for energy conservation at the University of Vermont [47].

2.7.6. Summary of Case Studies

From all of the above it can be concluded that for a successful energy management program at a tertiary institution, the following is required:

- Establishment of an Energy Policy.
- Energy Audit.
- Benchmarking of Buildings.
- Installation of meters to monitor energy consumption patterns.
- Energy Management and Control System.
- Efficient Thermal Plant, if air-conditioning is a major requirement.
- Motor replacement, where feasible.
- Reduction of energy and maintenance costs on plant equipment.
- Awareness.
- Energy Management Council.
- Improvement of Interior Lighting Efficiency.
- Cogeneration.

This is not an exhaustive list of the measures that should be taken to ensure success but the abovementioned points have been a common thread in the case studies analysed above.
Now that a background on the subject has been established and the important aspects of the programme have been identified, a flowchart for action should be established.

Fig 2.4 shows the flowchart is being followed to implement the energy management program. The most important point of the flowchart is that the entire process is a closed continuous loop. Therefore the program had to be implemented so that it could sustainable.

Step 1 involves creating an Energy Committee and soliciting employees' co-operation/support.

Step 2 requires conducting initial energy surveys. These surveys will form the basis of the goals and targets of the programme.

Step 3 is the actual energy audit. This will involve setting up an audit team who will review engineering information and data. Schedules will also be created to conduct the detailed audit.

Step 4 is the identification of and the analysis of the Energy Conservation Opportunities (ECOs). This is an evaluation phase where the overall system efficiency, operating procedures, maintenance procedures and measured data are analysed. This will form the basis for the cost/benefit risk analyses.

Step 5 is the implementation of the measures that have been recommended as a result of step 4. This step requires getting approval, proposing budgets for capital expenditure and implementing the measures approved.

Step 6 requires monitoring and collecting the technical data from the measures implemented. This is then compared with the targets set out earlier.

Step 7 requires the establishment of reporting and control systems. This involves setting measurement procedures, performance budgets and energy budgets. This step works on the principle of controlling and metering only the main energy functions. Focus controls on those functions that account for a majority of the costs - the 20/80 principle - 20% of the processes account for 80% of usage.

Step 8 is an interim action that calls for checking for variances and finding reasons for these variances. Corrective action is then implemented.

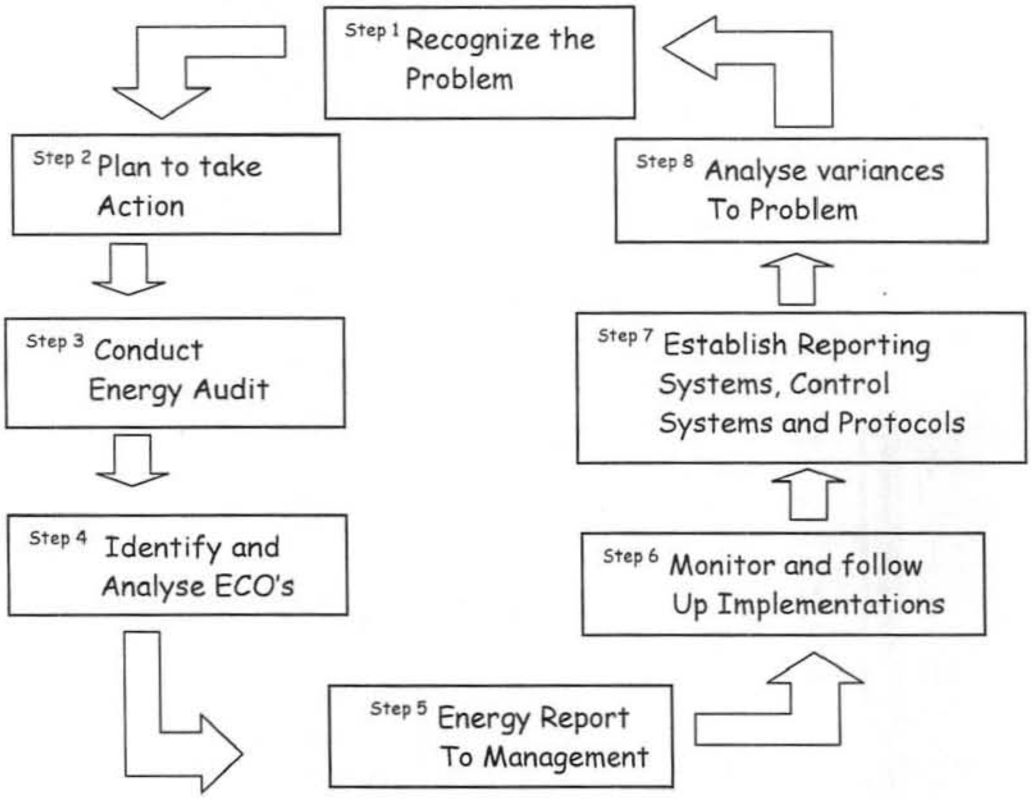


Fig. 2.4: Flowchart indicating steps to be followed in Energy Management Program

The process will then start all over again. It should be noted that the first iteration of this process is very time and resource consuming but any subsequent iterations is fairly quick, provided that the first iteration was implemented effectively.

Chapter 3

Overview of An Energy Management Program

3.1. Structuring for Energy Management

Energy Policy	Organising	Motivation	Information Systems	Marketing	Investment	
Active commitment of top management	Fully Integrated into General management	All Staff accept responsibility for saving energy	Comprehensive system with effective management reporting	Extensive marketing within and outside organisation	Positive discrimination in favour of "green scheme"	4
Formal Policy but no commitment from top	Clear delegation and accountability	Most major users motivated to save energy	Monthly monitoring and targeting for individual premises	Regular publicity campaigns	Same appraisal criteria used as for all other investment	3
No Policy Adopted	Delegation but line management and authority unclear	Motivation patchy and sporadic	Monthly monitoring and targeting by fuel type	Some adhoc staff awareness training	Investment with short term payback only	2
Unwritten set of guidelines	Informal part time responsibility	Some staff awareness of importance of energy saving	Invoice checking	Informal contacts used to promote energy efficiency	Only low cost measures taken	1
No explicit policy	No delegation of energy management	No awareness of the need to save energy	No information system or accounting for consumption	No marketing or promotion	No investment in energy efficiency	0

Fig. 3.1: Energy Management Matrix

The energy management matrix shown in Fig 3.1 above helps an organisation/institution to identify where they are in terms of their energy management practice, and gives them an opportunity to identify where they want to be [48].

The aim should be to move up through the levels towards current best practice and, in doing so, develop an even balance across all columns [48].

Level 0

Energy management is not on the organisation's agenda. There is no energy management policy, no formal energy management structure, no means of reporting, and no specific person in charge of energy use.

Level 1

Small steps towards energy management. While there is no official energy management policy, an energy manager has been appointed. The energy manager promotes an awareness of energy matters via a loose network of informal contacts with those directly responsible for energy consumption. This person also responds to requests for advice on an ad-hoc basis.

Level 2

Energy management is acknowledged as important by senior management but, in practice, there is little active commitment or support for energy management activities.

Level 3

Senior managers acknowledge the value of an energy reduction program. Energy consumption issues are therefore integrated into the organisation's structure. There is a comprehensive information system and established system of reporting. There is also an agreed system for energy management and investing in energy efficiency.

Level 4

Energy consumption is a major priority throughout the organisation. Actual performance is monitored against targets and the benefits of energy efficiency measures calculated. Achievements in energy management are well reported and energy consumption is related to its impact on wider environmental issues. Senior management is committed to energy efficiency.

At the beginning of this project the University of KwaZulu-Natal was between level zero and level one on the energy management matrix. This indicates significant potential for energy management.

The eight critical factors in organising an effective energy management program (which are integrated into the matrix above) are as follows [49]:

- a.) Obtain top management commitment.
- b.) Create an energy policy.
- c.) Obtain people commitment.
- d.) Set up a communication channel.

e.) Change or modify the organisation to give authority and commensurate responsibility for the conservation effort and develop an energy management program.

f.) Set up a means to monitor and control the program.

g.) Investment.

h.) Energy Auditing.

3.1.1. Obtain Top Management Commitment

At any level of the corporate structure, an individual should understand the incentives and motivations of top management. An alert energy manager will become aware of the hidden lines of authority and the key persons who make decisions. These key persons should be convinced of the positive merits of an energy management program before it can be successful. Therefore, it is the energy manager's job to see that the proper facts are presented through the proper channels to convince top management that they should make the energy commitment. This commitment should be a formally communicated, financially supported dedication to reducing energy consumption while maintaining or improving the functioning of a facility. The commitment should be active and clearly communicated to all levels of the organisation in terms of words and actions by top management.

3.1.2. Create an Energy Policy

An energy policy is a formal statement that is made by a government, party or person through which the course that is being adopted with respect to energy is defined [5]. The energy policy defines the direction of the energy management programme and is specific to each institution. Energy policies ensure the sustainability and transparency of the energy management programme and are statements of corporate commitment towards environmental harmony through the activity of reducing energy costs per product or business process. More simply put, an energy policy states what an institution intends doing about energy management and the goals they hope to achieve. An energy policy should not be confused with an energy strategy. The policy defines what the institution intends doing regarding energy whereas the strategy determines how it will be accomplished.

An energy policy has three essential components and should not be longer than a single page in order to maintain programme focus [5]:

- *Declaration of Commitment*

  The written support of top management sets the tone for the energy policy. As the name implies, it is a declaration that ensures that the management of energy will be sustained and supported as one of the many vital activities within the institution. For example:

"As part of its environmental strategy, the University of Warwick is committed to the responsible management of energy and practices energy efficiency throughout all its premises, plant and equipment wherever it is cost-effective to do so" [50].

- *Mission Statement*

  The mission statement is more specific than the declaration of commitment in the sense that it defines the focus of the energy management programme. Some examples are:

  - "To provide the most reliable and economical utility services for a safe, comfortable and productive learning, research and work environment for the campus community at the University of Houston [51]."
  - "To control the energy consumption in order to avoid unnecessary expenditure, improve cost-effectiveness, productivity and working conditions, protect the environment, prolong the life of fossil fuels and investigate and promote the use of renewable fuels [52]."
  - "To guard in a responsible manner over energy usage on campus as a scarce, necessary and expensive resource and to provide maximal benefit to the users in return for the minimum energy consumption and cost [32]."

- *Programme Goals*

  The goals of the energy management programme determine the specific objectives of the institution in order to achieve the mission statement. The goals will eventually determine whether the energy management programme has been successful or not. For example [52]:

  - To ensure that commitment is obtained from staff at all levels within the University on aspects of energy efficiency.
  - To purchase fuels and energy sources at the most economic costs.
  - To reduce the amount of pollution caused by energy usage, particularly emissions which are the main contributor to global warming.
  - To annually invest 50% of the previous energy saving costs in order to further reduce energy usage across the University.
  - In order to ensure its effectiveness, this policy will be reviewed and amended annually.

Occasionally a quantifiable target may also be included in the goals. Once a set target has been reached, a new target can be set either along the same line or towards another objective of the energy management programme. For example:

- To achieve a 2% energy saving each year for the next 3 years by good housekeeping supplemented by capital spending not exceeding R 50,000 per year [50].
- Reduce energy consumption by 20% in the next fiscal year [53].

The interaction of these three components is illustrated in Fig 3.2. If all the goals have been achieved, the mission statement will have been satisfied [5].

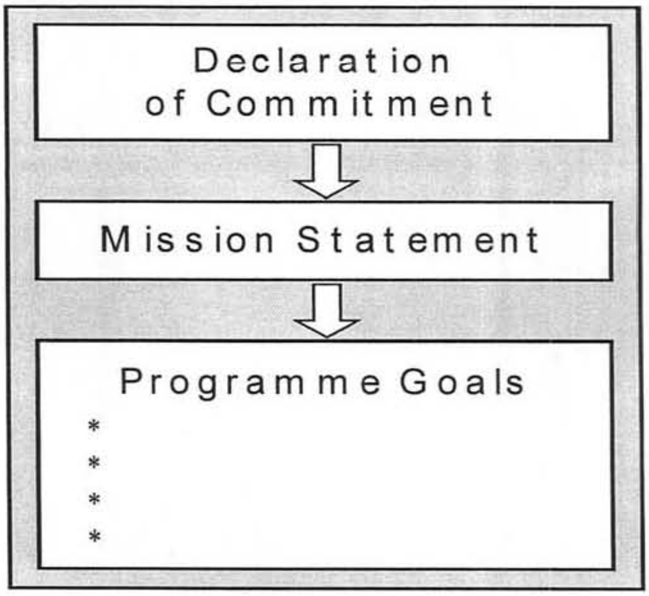


Fig. 3.2: Components of an Energy Policy

3.1.3. Secure People Commitment

An energy management program can be successful only if it arouses the participative interests of people at all levels of the tertiary institution. Ideas should be encouraged with rewards for significant contributions to the energy management program. Staff and students who participate and who feel themselves partners in the planning and implementation of the program will be more inclined to share pride in the results.

Communicating with staff and students on the subject of energy can be accomplished in many different ways: face to face discussion, seminars and workshops, distribution of informative and descriptive literature and most of all, through sincere practice of conservation on the part of management at all times.

The use of newsletters, bulletin boards, email and intranets for illustrating energy conservation objectives and accomplishments will help impress upon staff and students the importance of such matters. Staff and student participation can be increased by communicating examples of energy conservation ideas being implemented, photographs of persons who submitted the ideas, and information on the savings realised.

Competition between faculties, departments or residences within the University in pursuing conservation of energy can also generate enthusiasm among the university community. Competitive programs can be initiated and should be encouraged. Acknowledgment of good ideas and positive reinforcement are keys to this approach. People should be shown why their help is needed, and a team approach should evolve. The most successfully planned program can be devastated by a single person trying to subvert the program.

A clear, concise list of firm do's and don'ts to guide staff and students in their work can be helpful in achieving energy conservation practices. Such lists should be distributed to all staff and students in the manner prescribed above. These lists should be updated as often as necessary.

3.1.4. Establish a Communication Channel

The purpose of this channel is to report to the organisation the results of your efforts, to recognise high achievers and to identify reward recipients. Use the channel to advertise the program and to encourage cooperation. The different media available that can be used as a communication channel have been mentioned above.

3.1.5. An Organisational Plan

An organisational plan using the above criteria should then be developed for both implementing and monitoring specific energy management programs. This plan should also

- Define the responsibility of the energy management coordinator or committee.
- Describe an effective communication system between coordinator and major divisions, departments and staff and students.
- Establish an energy accounting and monitoring system.
- Provide the means for educating and motivating staff and students.

3.1.6. Monitoring and Controlling the Program

The translation of "You can't manage what you can't measure" into energy management terms means "You can't manage energy if you don't measure it". Unless there is a positive understanding of energy consumption at individual buildings or departmental levels, there is no valid way of identifying energy saving opportunities.

Monitoring the energy management program, for large energy users like the University of KwaZulu-Natal, involves the installation of a full information management system or data acquisition system enabling identification of past savings and continuous opportunities for investment, meeting the organisations financial parameters. A great deal of emphasis is placed on load measurement because it is this activity that allows for the discovery of energy intensive end-user groups. Being able to prioritise end-user groups according to their contribution to the total energy cost ensures that those groups that are highly energy intensive are addressed first. This ensures that scarce financial and labour resources allocated for energy management are utilised in the most efficient manner.

The number of measurement points should be carefully calculated to avoid unnecessary monitoring and information overload. With the instrumentation technologies available today, anything can be measured and controlled but always at a price. Therefore it is prudent to plan the measurement points wisely to ensure that scarce financial and human resources are used effectively.

The data acquisition systems used for energy savings verification can vary with the retrofit being monitored and the length of the monitoring period. Metering is a crucial part of the data acquisition. Some technical reports on the different types of meters and metering required for energy management can be found in Appendix A.

Audits based on a well-designed metering system will frequently yield surprising results and may often identify considerable savings. Through proper monitoring, recording and analysis, the use of meters can lead to corrective actions that produce the desired result of reducing energy per unit production or per service performed. Experience has shown that a 1-2% reduction in consumption can be achieved after meters are installed just by letting users know that they are being monitored. Up to a 5 % total reduction can occur when users then become proactive in better managing the use of their energy. Some basic reasons to meter energy consumption are as follows:

- Charge out energy to individual departments.
- Accountability for energy used.
- Efficiency of utility equipment and systems.
- Provide information for audits of energy projects.
- Maintenance work: identify locations of performance problems, and provide feedback to managers.
- Identify potential future energy savings.

3.1.7. Investment

Management should show a positive discrimination in favour of a "green campus" scheme. This includes investment in both short term and long term projects. Realistic goals should be established that are specific in both amount and time. The goal should take into account the consideration of capital expenditure and diminishing returns.

3.1.8. Energy Auditing

A good energy audit is a key energy management tool. The basic functions of energy management (planning, organizing, decision making and controlling) depend on the information obtained from the audit. The energy audit supplies the information necessary to manage energy use.

An energy audit determines where and how energy is being used. It identifies measures to improve efficiency and provides a benchmark against which future building performance can be compared. Conducting a good energy audit involves

- Following the correct procedures.
- Making use of effective instrumentation.
- Performing energy estimates and savings calculations.
- Obtaining energy end-use profiles.

There is a direct relationship between the extent of data collection and consolidation, and the subsequent evaluation of energy conservation opportunities. While an insufficient database may prevent the identification of several energy-saving opportunities, too extensive a baseline survey may prove unnecessary and wasteful by diverting funds and time from more rewarding conservation opportunities. Six categories for energy use should be analysed as the tour is conducted. These six categories are as follows:

a.) Lighting: Interior, exterior, natural and artificial.
b.) The heating, ventilation and air conditioning (HVAC) system and the heating and cooling effects of conduction, convection and radiation.
c.) Motors and drives.
d.) Processes.
e.) Other electrical equipment (transformers, contactors, conductors, switchgear etc).
f.) Building shell (thermal infiltration, insulation and transmission).

The key observations that should be noted during the audit for each of the six categories mentioned above are set out in Appendix B.

3.2. Overview on how to Conduct Building Energy Audits

Of the total energy consumed in the day-to-day use of a building, the term "building energy" denotes the energy consumption relating to and determined by the type, design and purpose of the building itself. It is not concerned with the process carried out by the occupiers, nor does it refer to the energy consumed in the manufacture of the materials of the structure. Predominantly, therefore, it comprises heating, cooling, ventilating and lighting i.e. controlling of the indoor environment. It may include some external lighting and "domestic" (not process) hot water and catering.

The method to conduct an energy audit, as outlined in this thesis, refers mainly to commercial and institutional buildings whose total energy consumption exceeds 100 000 kWh per month. Within commercial and institutional buildings most of the total energy is used for controlling the environment within the buildings rather than for the processes. A proposed work procedure flowchart for energy audits in buildings is shown below in Fig 3.3.

Large commercial and institutional buildings present a principal target for the formalised study procedure outlined here, because of their considerable energy use. Air-conditioned buildings present a major target for study because:

- The golden age of air-conditioning development occurred before the limitations and cost of energy resources were fully appreciated, so that existing systems may not be energy efficient, and may be over-designed for a temperate country like South Africa.
- Air-conditioning load is an extremely energy intensive load in a commercial and institutional building environment.

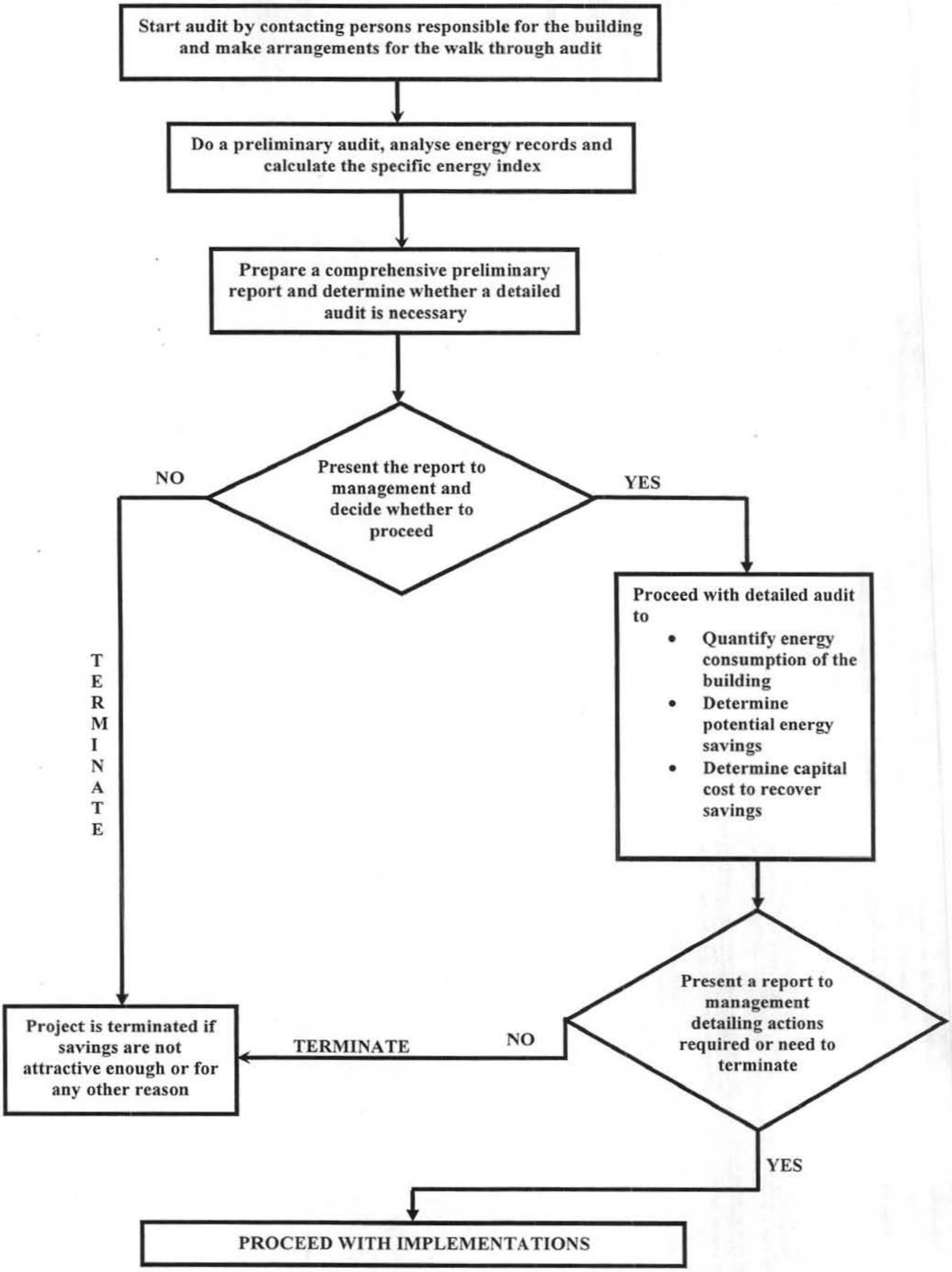


Fig.3.3: Flowchart to conduct Energy Audit

A comprehensive energy audit of a building, which is normally done in phases, comprises of the following:

- Measure, record and analyse all the energy consumed in the building.
- Compare this information with standards available for buildings of a similar structural type, usage pattern and climatic environment.
- Identify potential cost savings in energy consumption and maximum demand.
- Prepare proposals with respect to the energy saving possibilities.
- Fix a budget value to the potential savings, payback period and program.

The energy audit team should comprise of people with a sound knowledge of management operations, engineering and finance. It is wise to have the support of both an electrical and mechanical engineer. The electrical engineer will handle control systems and distribution systems while the mechanical engineer will deal with mechanical systems design and heat transfer problems.

A comprehensive audit can be divided into three distinct phases.

Phase 1 is the preliminary audit. The preliminary audit consists of the following:

- Data collection.
- Walk through audit.
- Analysis of results.
- Calculation of specific energy consumption index for the building.
- Conclusions and recommendations (especially in terms of the need or otherwise to continue with the detail audit).

Phase 2 is the detailed audit. This consists of:

- Collection of detail information.
- Energy recording over specific period.
- Analysis of results.
- Identification of saving potential.
- Quantification of energy savings and related capital cost.
- Recommendations.

The third and final phase is the recommendations in respect of:

- Energy management actions.
- Capital improvement.

- Measuring of results achieved and the relevant control measures necessary for ongoing energy management.

3.2.1. PRELIMINARY AUDIT

The object of this audit is to gather enough information of the building equipment and energy consumption during the walk through audit to estimate and evaluate whether savings in energy and costs can be achieved and whether it is feasible to do a detailed study for the next phase of the project.

This preliminary audit consists of the acquisition of information and a physical investigation of the design and layout of the building as well as the equipment in the building. This is known as the walk through phase. This is followed by an analysis of the information acquired.

The walk through phase of the preliminary audit consists of a comprehensive daytime investigation and a condensed nighttime and cleaning phase. This phase has the purpose of establishing a reasonable feeling for the energy consumption systems in the building as well as their energy efficiency.

3.2.1.1. Documentation

The documentation outlining the following is required to conduct the preliminary audit:

- Energy accounts and other maintenance cost records must be gathered for a period of at least one year and preferably three. These bills should be reviewed to establish the existing pattern of electrical usage and to identify those areas where energy consumption could be reduced. Historical data on a month-by-month basis of electric usage should be recorded, preferably in graphical format, to facilitate reference, evaluation and analysis. Some of the items that should be recorded are
  - Billing month.
  - Days in billing cycle.
  - Kilowatt-hours.
  - Time based kilowatt-hours (if billed on this basis).
  - Kilovar hours.
  - Power factor.
  - Heating or cooling degree days.
  - Additional columns for remarks (such as vacation or high vacancy periods).
- Different tariff options available from the supply authorities.
- Available architectural and engineering drawings.
- Specifications of control systems, to be checked against actual operation.

- Specifications of control systems together with set point information and control schedules. Wiring diagrams and as built drawings should also be acquired.
- Operational and maintenance manuals, maintenance records and complaints books should also be acquired if available.

The requirements of the building occupant should also be established before making the audit. Some of the aspects that should be considered are:

- Standards desired by owner/occupants in terms of:
  - Lighting.
  - Temperature.
  - Humidity.
  - Fresh air intake.
  - Ventilation.
- Pattern of usage in building:
  - Hours occupied and hours of operation of equipment for different areas.
  - Periods when cleaners are busy and method of cleaning.
  - Energy consciousness of occupants and staff.

The audit tables are shown in Appendix B.

3.2.1.2. Analyzing the Energy Accounts

Information from the energy cost accounts (Table 1 – Appendix B) should be used to prepare the following graphs:

- Monthly maximum demand and kilowatt-hour consumption for the building over preferably a two-year period.
- Half hour interval maximum demand for a week or two week period whereon preferably the contributors of the main energy consumers are shown.

Analyze the following from the graphs:

- Seasonal tendencies.
- Change from year to year.
- Base loads and peak loads.

These analyses should be done in terms of consumption (kWh), as well as maximum demand (kVA or kW), which information is obtained during the detail audit. These values should be compared with the values obtained from the energy bills to establish whether the measurements are representative of the charged maximum demand.

3.2.1.3. Determining the Building Index and Comparing it With Standard Index

The audit tables are shown in Appendix B. From the information in Table 1 and other available information, determine the specific energy consumption indices for the building and complete Table 6. By comparing the indices with the standard for similar buildings in Appendix B, it can be determined how energy efficient the building is. Should the building not compare favourably with the standards, further detailed investigation of the main energy consumers will obviously be necessary.

Should the operating hours of the building deviate from the standard 2500 hours per annum, adjustment in the calculations will have to be made. Refer to the correction factors given in Appendix B.

3.2.1.4. Estimation of Component Energy Consumption

Estimate the component energy consumption, using the information in Table 3, and from this information complete Table 7.

Should separate metering facilities be installed, or should separate energy sources be utilized, the component usage can be more accurately determined. Most likely, during the detail audit more specific attention will have to be paid to this aspect, with a view to accurately quantifying these estimates.

3.2.1.5. Recommendations

The results of the preliminary audit, which consist of the quantitative analysis together with the quantitative impression gathered during the walk through phase, **are used primarily to establish whether a detailed audit is feasible.** This phase is concluded with the relevant motivation in this regard to management. The report should also include a summary of the potential savings as set out hereunder:

- Potential for tariff change and saving.
- Potential for power factor correction.
- Lighting
  - ❑ Fittings are not energy efficient.
  - ❑ Lights are on during night.
  - ❑ Potential use of natural light instead of artificial light.
  - ❑ Lighting.

- Air-conditioning
  - Set internal temperature higher than maximum acceptable level.
  - The fresh air cycle can be improved.
  - On and off switching can be improved.

The main reason for the information gathered from the walk-through audit is to establish whether a business case for energy management exists. The major energy users and major potential areas for savings are also identified during the walk-through audit. This information is then used to inform the direction that the detailed audit will take.

More information and methodology on how to perform a detailed audit is included in Appendix B

3.2.2. Expected Recommendations from Detailed Audit

The final report should have all the aspects that were considered and must be tabled together with:

- Cost of installation.
- Estimated saving in energy cost/year.
- Estimated life expectancy of equipment that will be installed.
- Estimated yearly maintenance cost.

The various options must be arranged in immediate, short term and long-term possibilities. The different actions and priorities could be considered as follows:

- **Immediate action (Good Housekeeping).**
  - Change to a more economical tariff structure if applicable.
  - Staff awareness.
  - All other aspects, which came to light during the study where savings could be achieved by adjusting settings, reducing lamps etc. (See appendix B).
- **Short-term action.**
  - Implementation of all aspects, which will give a payback period of less than 2 years. It could be that management may wish to only implement those actions that have a payback period of less than 12 months initially and the rest once the savings are proven.
- **Long term action.**
  - All the aspects, which will give a payback period of more than 2 years, should be reconsidered at regular intervals as it may be that with further

increases in energy costs and improved technology these options become more viable.

Chapter 4

Fundamental Energy Analysis Theory

4.1. Fundamentals of Energy Analysis

4.1.1. Electricity Tariff

Each year a tariff structure is submitted by each electricity distribution company or utility to the National Electricity Regulator (NER) and this tariff is either approved in its submitted form or modified after rate hearings by the regulatory body. The policies of the NER require the introduction of cost reflective tariffs. However some cross-subsidisation still exists where social policies require it [54]. The tariff structure, if cost reflective, will in most cases not be amended but a price increase is what will be submitted to the regulatory body for approval on an annual basis.

Each tariff has two sections:

- Rules and regulations.
- Rate schedules.

Rules and regulations are conditions under which a utility will supply power to a customer. These include billing practises, rights of way, metering, continuity of service, power factor, line extensions, temporary service and other details [10].

Rate schedules are the prices for electricity supply to different classes of customers. The four common classes are residential, commercial, industrial and street or area lighting. There may be several further tariff subdivisions on each customer class based on load magnitude. Special tariffs and Negotiated Pricing Agreements (NPA's) are also available for very large consumers.

The electric rate structures vary greatly from utility to utility, but they all have common features. Commercial and industrial customers have three to four major components to their electricity bill. These are [54]:

- **Customer cost:** A basic charge is levied on certain customers. A connection fee is payable by new customers in order to contribute to the cost of the additional connections or basic charge.
- **Energy Cost** normally a c/kWh charge.
- **Demand Cost** either a R/kW or R/kVA charge.
- **Service Charges** are designed to recover a share of the cost incurred irrespective of there being any consumption eg. Billing, meter reading, running costs, administration costs etc. This charge is normally applied as a percentage of the energy cost or demand cost or the total usage cost.

The University of KwaZulu-Natal is supplied electricity by Durban Electricity. Durban Electricity is the largest electric utility in South Africa. Prior to 1 January 2003, their Time-Of-Use (TOU) tariff structure was very similar in nature to Eskom's time-based tariff called MegaFlex. The major difference between these two tariffs was that DE's TOU tariff had two demand charges whereas Eskom had just one demand charge [54].

For the purpose of all subsequent financial calculations, the Time-Of-Use (TOU) tariff post 1 January 2003 will be used to calculate possible savings. Some of the historical costs will obviously be based on the older tariff structure. The amendment to this tariff will not have much bearing on the analysis since the overall maximum demand and the maximum demand always occurred at the same time. More details on tariffs, as well as the structure of the Durban Electricity TOU tariff are included in Appendix C.

4.1.2. Electrical Load Analysis

The fundamental concepts that need to be understood in order to perform an electric load analysis are listed below.

- Load Profile.
- Load Duration Curves.
- Base Load.
- Power Factor.
- Load Factor.
- Coincidental Maximum Demand
- Diversity Factor.
- Disaggregated Load Profiles.

These concepts will now be described in more detail.

4.1.2.1. Load Profile

A load profile is a graphical plot of power consumption for a specified time period (typically a day, week or month, as shown in Figs 4.1 – 4.3). Two essential elements can be obtained from a load profile. The maximum amount of power consumed (termed Maximum Demand) is the point of the greatest power consumption for the period under consideration and the sum of the area under the profile is the amount of energy that is consumed. Load profiles also provide an indication of the times that specific loads are being used as shown in the figures below [36].

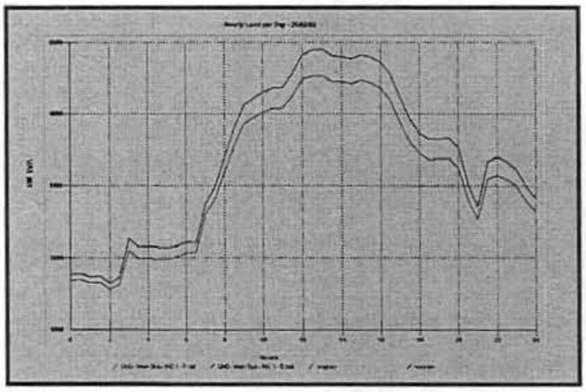


Fig 4.1. Daily Load Profile

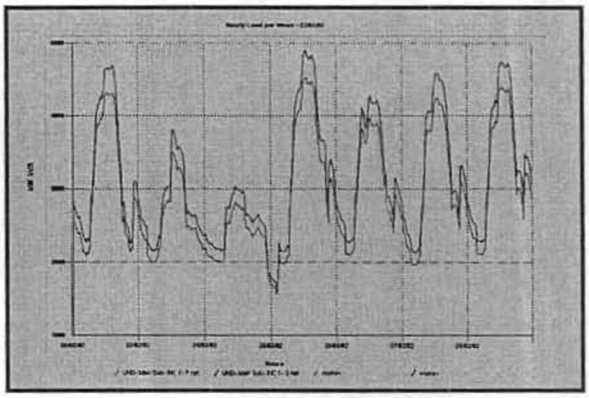


Fig 4.2. Weekly Load Profile

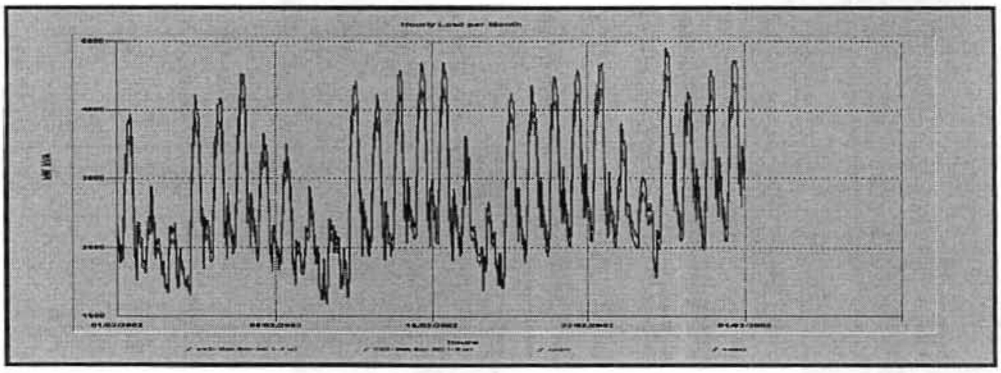


Fig 4.3. Monthly Load Profile

4.1.2.2. Load Duration Curves

The load duration curve is constructed by sorting the load data from the highest value to the lowest value and then plotting this data against the duration interval [36]. Note that the duration interval on the X-axis does note denote chronological hours. This plot is used to show the load distribution for each total demand value. An almost horizontal curve indicates a constant demand for electricity whereas a more negative curve indicates a time dependent process. Fig 4.4 illustrates the load duration curve of the total University load as presented in load profiles. This graph is extremely useful in any load management and load control analysis.

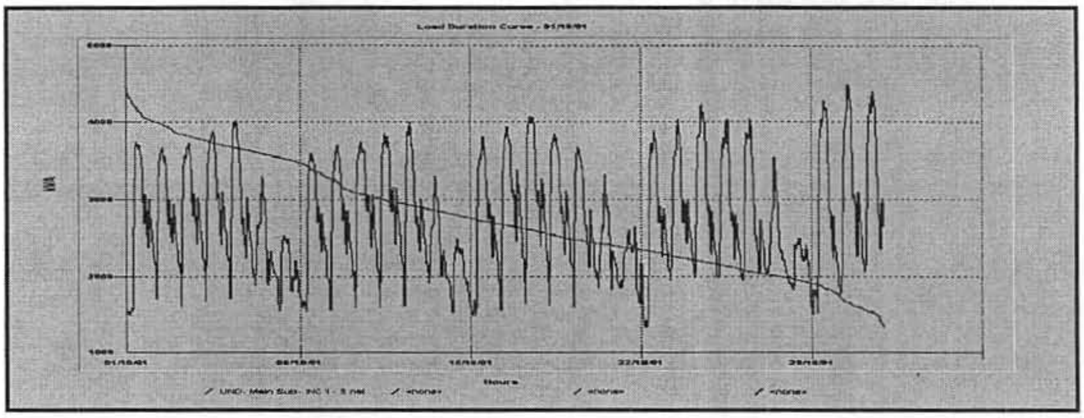


Fig 4.4. Load Duration Curve

4.1.2.3. Base Load

The minimum amount of electric power delivered or required over a given period of time at a steady rate. Base load constitutes the 100% portion of the load duration curve above [36]. Fig 4.5 shows the baseload highlighted in red.

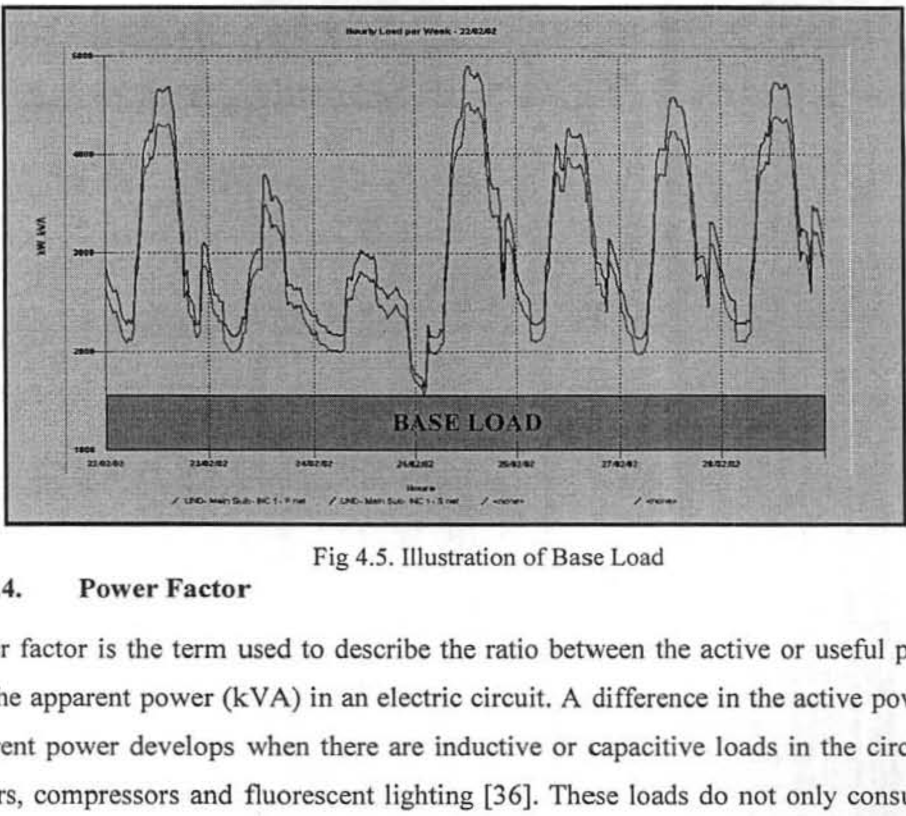


Fig 4.5. Illustration of Base Load

4.1.2.4. Power Factor

Power factor is the term used to describe the ratio between the active or useful power (kW) and the apparent power (kVA) in an electric circuit. A difference in the active power and the apparent power develops when there are inductive or capacitive loads in the circuit such as motors, compressors and fluorescent lighting [36]. These loads do not only consume energy but also store it in electric or magnetic fields. The active power is not affected but the apparent power is now higher because of the reactive power that is developed in this circuit, which cannot be used. This has an impact on your maximum demand costs.

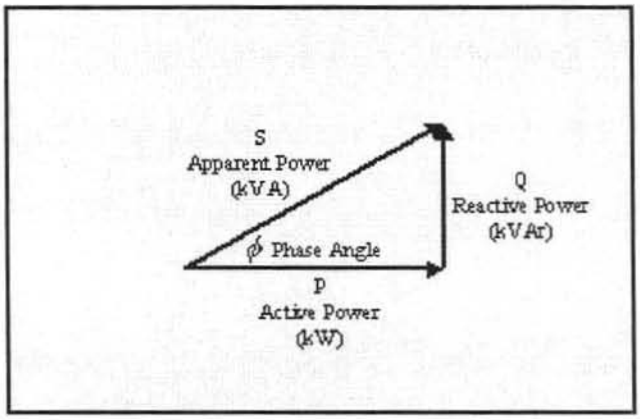


Fig 4.6. Power Triangle

$$Power\ Factor(PF) = \cos\phi = \frac{P}{S} = \frac{Active\ Power(kW)}{Apparent\ Power(kVA)} \qquad (4.1)$$

The power is represented by the equation 4.1 with reference to the power triangle in the Fig 4.6. The power factor has an impact on the amount of power that is dissipated in electric circuits and there are many technical examples in texts. The power factor cannot be greater than 1.

4.1.2.5. Load Factor

The load factor is a utilisation factor and is expressed as the ratio of the average demand to the maximum demand [56]. Simply put, the load factor is a ratio between the actual energy consumed during a period and the energy that could have been consumed had the demand remained at the maximum demand for that same period. The value for the load factor cannot be greater than 1.

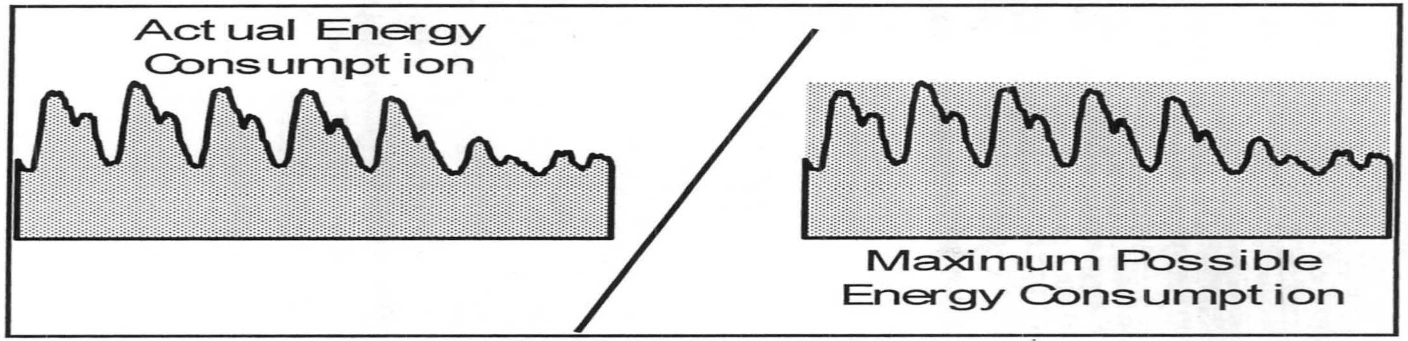


Fig. 4.7: Load Factor Explained

The load factor can be calculated using equation 4.2 [56].

$$Load\ Factor\ (LF)_{\ for\ period} = \frac{kWh\ Consumed_{\ in\ period}}{Maximum\ Demand_{\ in\ period} \times Number\ of\ Hours_{\ in\ period}} \quad (4.2)$$

4.1.2.6. Coincidental Maximum Demand

The sum of two or more demands that occur in the same time interval [36]. The contribution that t he individual customers or end-users make towards the maximum demand of the system will vary. The result of this is that the real costs of the system are not necessarily caused by all of the customers connected to that system. Fig 4.8 shows that although the maximum demand of each load occurs at a different time, the overall maximum demand of the loads combined has a maximum demand which does not coincide with the individual maximum demands.

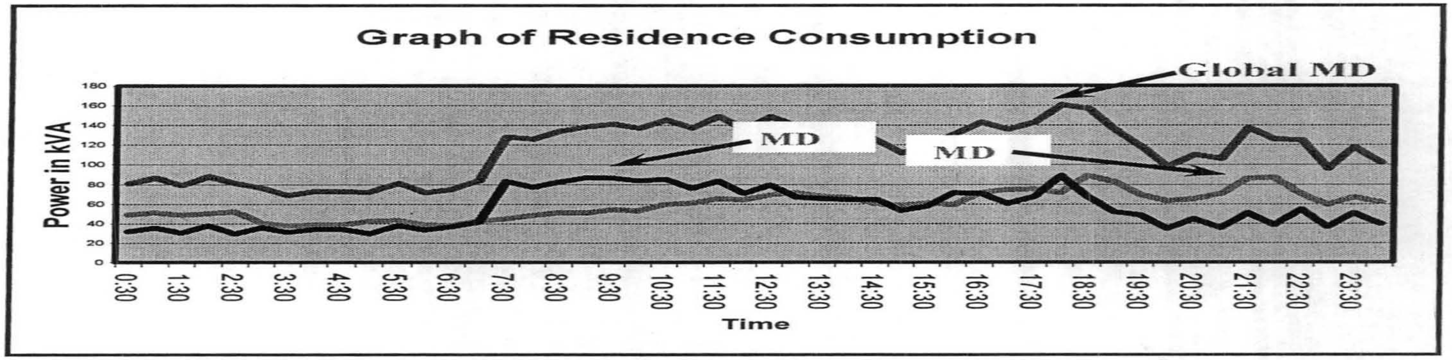


Fig 4.8. Illustrations for Coincidental Maximum Demand

4.1.2.7. Diversity Factor

The diversity factor of a number of customers, when considered from a single point of supply is defined as the ratio of their separate maximum demands to their combined maximum demand. It is a measure of the real maximum demand on a system at a mutual point of supply and is given by the next equation. The diversity factor is always greater than or equal to 1.

$$Diversity\ Factor\ (DF) = \frac{\sum_{i=1}^{n} Maximum\ Demand}{Combined\ Maximum\ Demand} \tag{4.3}$$

For a demand based tariff, a diversity factor of 1 is not a desirable condition, as it would imply that the maximum demands of the individual loads all occur at exactly the same time. A higher value of diversity factor implies a lower coincidental demand, which ultimately means lower total demand costs. A higher value of diversity factor also indicates a well managed or well planned system.

4.1.2.8. Disaggregated Load Profile

Plotting separate loads on the same set of axes produces a disaggregated load profile. The function of the disaggregated load profile is to gain insight into the load distribution and to display the total load profile. This is illustrated in Fig 4.9 below.

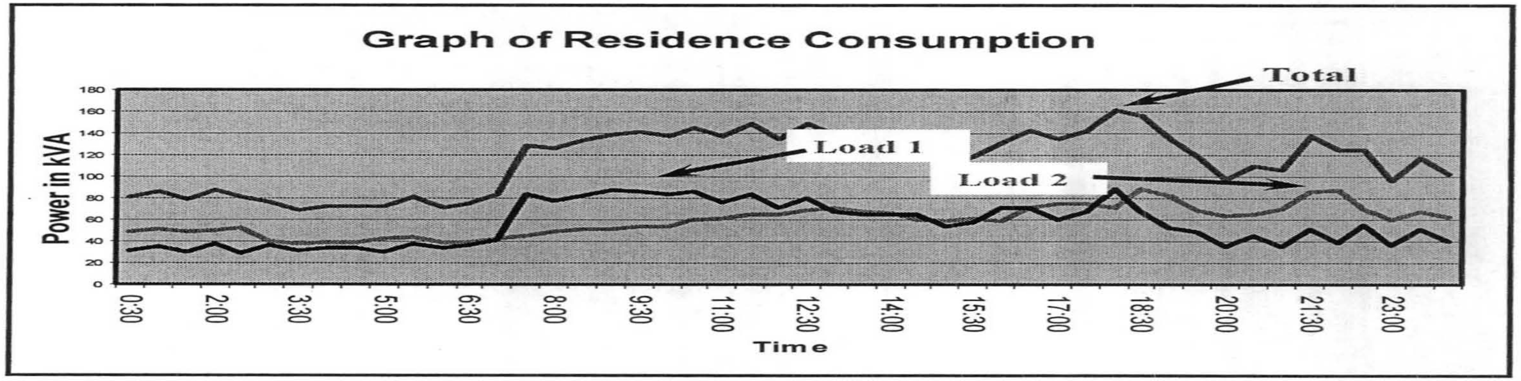


Fig 4.9. Illustrations for Disaggregated Load Profile

4.1.3. Financial Analysis

To justify an energy investment cost, knowledge of life-cycle costing is required. The life-cycle cost analysis evaluates the total owning and operating cost. It takes into account the "time value" of money and can incorporate energy cost escalation into the economic model. This approach is used to evaluate competitive projects. Life cycle cost analysis considers the cost over the life of the system rather than just the initial cost.

The economic 'bottom line' of any energy efficient or cost saving measure will determine whether implementation will proceed. It is important, therefore, that the approaches used in evaluating the economic viability of any energy system are well understood. Simple assumptions, such as the choice of discount rate, will greatly affect the outcome of an economic evaluation.

4.1.3.1. Life Cycle Costing

The use of a standard for economic evaluation of energy management projects is seen as important for the following reasons:

- To bring a degree of uniformity to the procedures for financial evaluation of energy management projects
- To permit an evaluation of the cost-effectiveness of competing energy management options

Energy professionals recommend life cycle costing as the most reliable methodology for determining the cost effectiveness of energy management projects in institutional, governmental, commercial and industrial applications [60].

The life cycle costing methodology involves adding up all the costs of a project over the term of the evaluation, with the costs in any year being discounted back to the base period. The discounting process seeks to reflect the time value of money and to reduce all future sums of money to an equivalent sum of money in the base period (eg in today's rand value, or rands at the start of the project). This discounting process estimates the present value of future costs.

The following assumptions are made in this approach:

- Initial capital costs are considered as a lump sum at the start of the analysis (ie in period 0).
- Other non-recurring costs such as replacement of plant and equipment may be required during the period of the analysis.

- All recurring costs (eg energy costs and operating and maintenance costs) begin to accumulate in the first period (i.e. the period after period 0).
- Costs in any period are lumped together and are considered to occur at the end of that period.
- Inputs such as salvage values are considered as negative costs.
- The rates at which costs increase may differ between energy and other recurring costs.

4.1.3.2. Some Definitions and Calculation Procedures

Cash Flow Diagrams

Cash flow diagrams are a graphical description of cash transactions. Receipts are indicated with an upward arrow and disbursements with a downward arrow. The length of the arrow is proportional to the size of the payment and the net cash flow per period is presented. A graphical representation of this is shown in Fig 4.10 below.

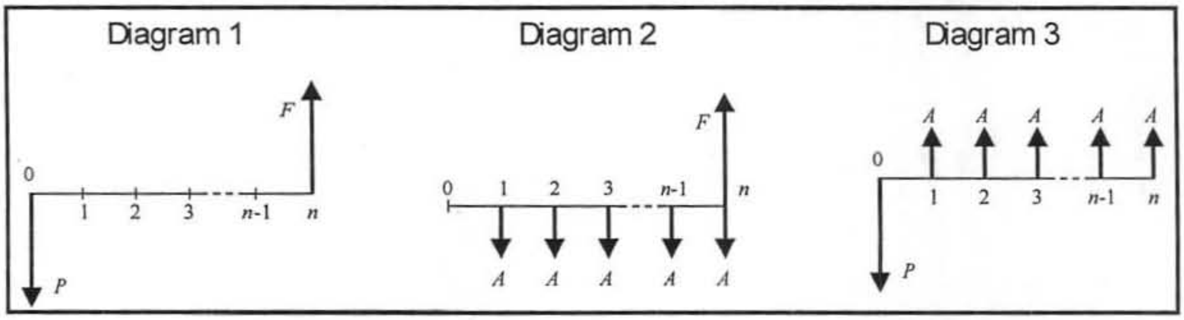


Fig 4.10. Cash Flow Diagrams

In Fig. 4.10. P represents the present value of the investment, F is the future value of the initial investment P, after a series of uniform payments A occurring over a period of n intervals (compounding periods), compounded at an effective interest rate of i.

Present Value (PV)

Present Value is the value of a future transaction discounted to some base date. It reflects a time value of money. The present day equivalent of a future cost, i.e. the present value, can be thought of as the amount of money that would need to be invested today, at an interest rate equal to the discount rate, in order to have the money available to meet the future cost at the time when it was predicted to occur.

$$PV = \frac{Fn}{(1+r)^n} \tag{4.4}$$

Where

Fn = cash flow, or any other value, in year n.

n = years (duration of compounding period)

r = discount rate

and $\frac{1}{(1+r)^n}$ is defined as the **single payment present worth factor**

If inflation is considered, the **single payment present worth factor** can then include the effects of both inflation and discount rate, and becomes a function of r, a & n:

$$\frac{(1+a)^n}{(1+r)^n} \tag{4.5}$$

OR

$$(\frac{1+a}{1+r})^n \tag{4.6}$$

Where

r = discount rate

a = escalation/inflation rate

n = years

Net Present Cost (NPC)

The Net Present Cost of a project is the sum of the Present Value (PV) of all costs over the period of interest, including residual values as negative costs. The total NPC of a project is a summation of all cost components including such things as:

- Capital Investment
- Non-fuel operation and maintenance costs
- Replacement Costs
- Energy Costs (Fuel costs plus any associated costs)
- Any other costs such as legal fees etc

If a number of options are being considered then the option with the lowest net present cost will be the most favourable financial option.

As an example consider a situation where a new process is to be introduced which will cost R 2,000 to install and R 100 per year to operate in today's rand value, and will last four years. The salvage value at the end of this time is expected to be R 200 (at that time). The net present cost for this option is given in Table 4.1 where operating costs are assumed to increase by 5% per year and a discount rate of 10% is to be used.

Year	Cost (in actual R's of the period)	Present Worth Factor	Present Value	Comments
0	R 2000	1	R 2000	Capital cost in Base period
1	R 105.00	0.9091	R 95.45	Costs are inflated by 5% per annum
2	R 110.25	0.8264	R 91.11	
3	R 115.76	0.7513	R 86.97	
4	R 121.55	0.6830	R83.02	
4	-R 200.00	0.6830	-R 136.60	Salvage value taken as negative
TOTAL			**R 2219.95**	**Net Present Cost**

Table 4.1. Illustrative Example of Net Present Cost

Net Present Value (NPV)

The Net Present Value of a project is the sum of the present values of all the benefits associated with the project less the sum of the present values of all the costs associated with the project.

$$NPV = -C + \sum_{i=1}^{n} \left(\frac{1+a}{1+r}\right)^{i} * S \qquad (4.7)$$

In a project with a single capital outlay of `C' at the start of the project and annual financial savings that increase at a rate of `a' from an initial figure of `S', the NPV can be given by equation 4.7.

Where

$$\sum_{i=1}^{n}\left(\frac{1+a}{1+r}\right)^{i} = PWF(a,r,n)$$

is the Present Worth Factor for a series of regular payments/savings

PWF (a,r,n) may also be referred to as the Net Present Cost Factor and the value can be determined from tables or from the formula:

$$PWF(a,r,n) = \frac{1-\left(\frac{1+a}{1+r}\right)^{n}}{\left(\frac{1+r}{1+a}\right)-1} \tag{4.8}$$

If the NPV of a project is positive then the project will provide a net financial benefit for the company. Such an approach can be used when evaluating energy management options, which will involve initial capital expense and produce subsequent energy savings. While the recommended appropriate method of analysis when comparing energy options is life cycle costing, other methods do exist.

Simple Payback Period (T)

This calculation reflects, in simple terms, the economic attractiveness of an energy option.

$$T = \frac{C}{S} \tag{4.9}$$

Where C = extra capital cost
S = estimated savings

Annual Equivalent Cost

This is a variation of the NPV method, which may be more meaningful to many people. Costs and benefits are reduced to a series of equal annual payments which when discounted and summed have the same total value as the initial outlay. This is equivalent to the calculation of a bank loan.

The Capital Recovery Factor (CRF), which is the reciprocal of the PWF, is used to convert a single payment `C' into the equivalent annual payment `A'.

$$A = C * CRF(a,r,n) = C * \frac{1}{PWF(a,r,n)} \tag{4.10}$$

Internal Rate of Return (IRR)

The internal rate of return (IRR) method solves the NPV equation for an interest rate that yields zero NPV. In other words, the IRR causes the project revenues to equal the project costs. The internal rate of return is thus the rate, i* that satisfies equation 4.9.

$$NPV(i\ ) = \sum_{t=0}^{n} \frac{Ft}{(1+i^*)^t} = 0 \tag{4.11}$$

where $0 \leq i^* \leq \infty$

The computation of the IRR requires a trial-and-error solution. Substituting a few discount rate values until the above equation is satisfied or until the NPV equals zero solves it. The IRR represents the equivalent rate lost (or earned) on the under recovered (or over recovered) balance of the investment. IRR can be calculated for a number of alternative projects in order to rank them. A higher IRR indicates that higher financial merit and negative figures are indicative of financial loss. Consider the sample cash flow in Table 4.2.

The expression to calculate the IRR is given by the following equation:

$$NPV(i^*) = -10000 + 4000\left\{\sum_{t=1}^{4}\left[\frac{1}{(1+i^*)^t}\right]\right\} \tag{4.12}$$

Substituting values for i^* in order to render the NPV equal to zero, yields an IRR equal to 21.86%.

Period	Cash Flow
0	-10,000
1	4,000
2	4,000
3	4,000
4	4,000

Table 4.2: Sample Cash Flow

Chapter 5

Results of Energy Audit

5.1. Profile of the University of KwaZulu-Natal

The University of KwaZulu-Natal is a tertiary education institution situated in Durban, Kwa-Zulu Natal. Durban is famed for its mild and sunny winter climate and year-round "fun-in-the-water" weather. Durban is blessed with a subtropical climate with sunshine for at least 320 days a year. Temperatures range from 16°C and 25°C during the winter months of June, July and August. Summer temperatures can reach 32°C with relatively high humidity during the summer months. The average annual temperatures are given in Table 5.1 below [43]:

The University of KwaZulu-Natal is made up of five separate campuses: the Durban Main campus (also known as the Howard College Campus), the Westville Campus, the Pietermaritzburg campus, Edgewood College and the Nelson R Mandela Medical School campus. It was decided to confine this study to the Durban Main campus (Howard College) for logistic reasons. **The Howard College Campus is sometimes referred to as the Main Campus in some of the explanations further on.**

The vital facility statistics of the Howard College Campus are as follows:

- 20 Buildings/Complexes excluding Residences.
- 13 Residential Complexes.
- Approximately 13 000 Fulltime and Part-Time students.
- 24 Hour Operational Hours (including Residences).

Aerial views of the campus from the east and west are shown in Figs 5.1 and 5.2 to illustrate the size and physical distribution of the various buildings and campus facilities.

Durban's Temperatures		
MONTH	**MAXIMUM TEMP °C**	**MINIMUM TEMP °C**
January	32.7	20.5
February	33.8	20.3
March	28.7	19.7
April	25.8	16.7
May	24.3	12.8
June	22.8	9.5
July	22.7	9.5
August	23.0	11.5
September	23.3	14.4
October	28.1	16.3
November	29.1	17.9
December	32.7	19.3

Table 5.1: Average temperatures for Durban

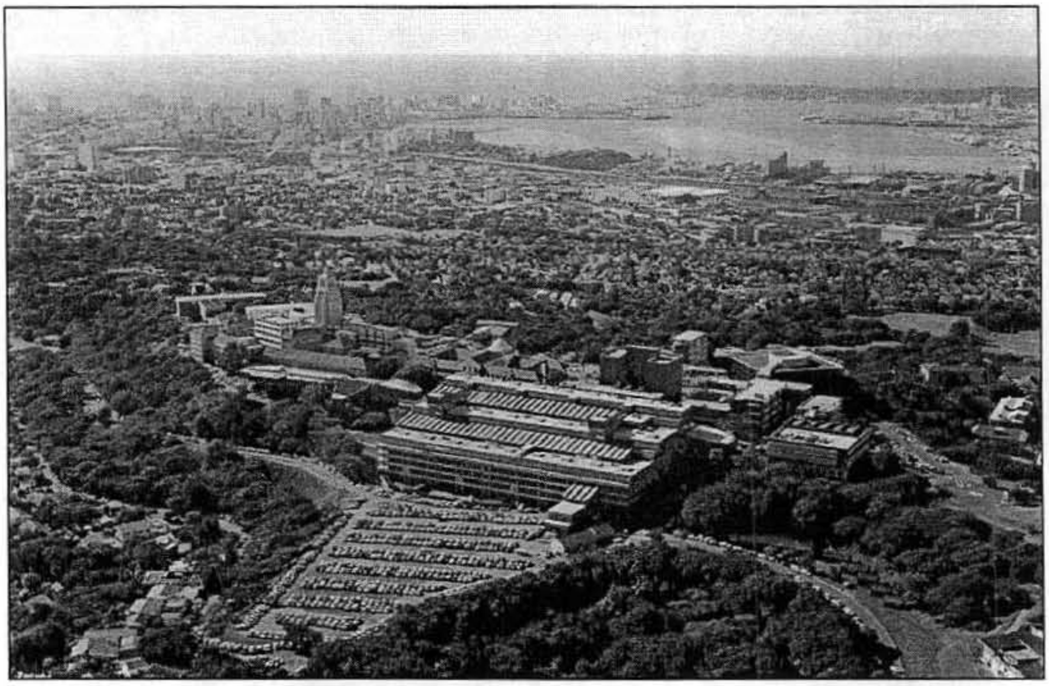


Fig: 5.1: Aerial View of Howard College from the West

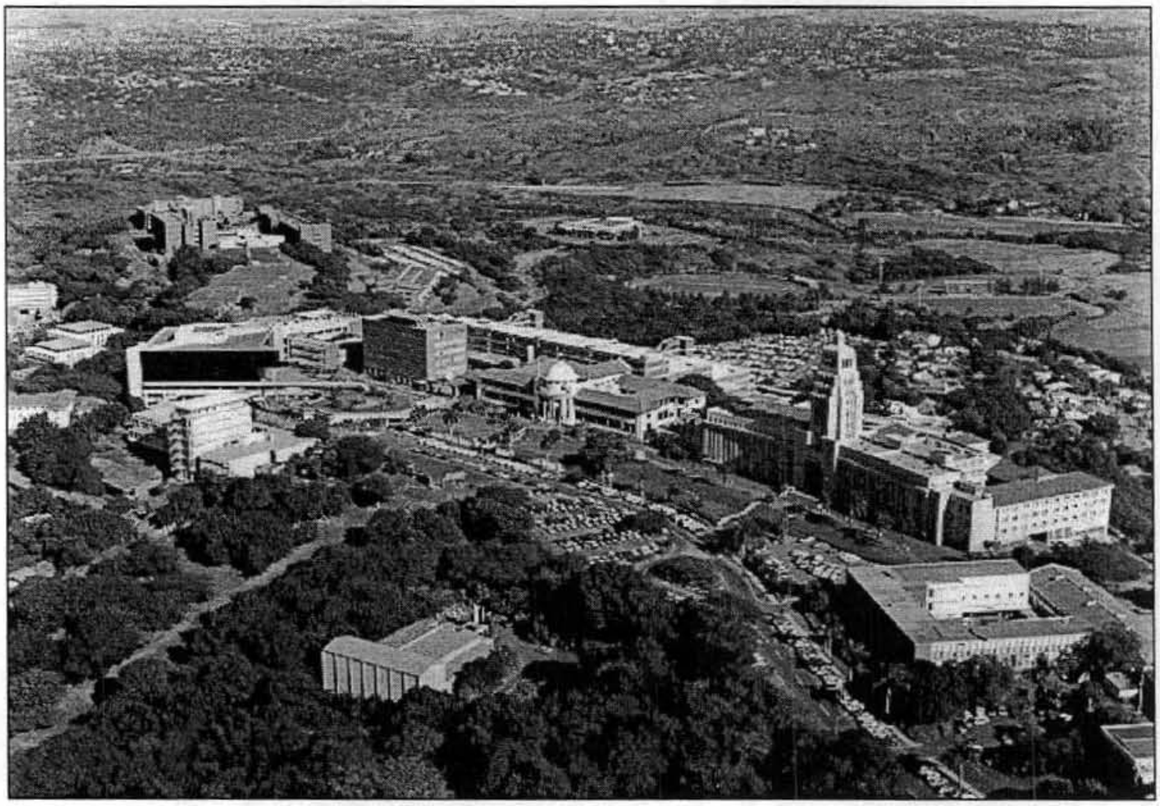


Fig: 5.2: Aerial View of Howard College from the East

The vital energy statistics of Howard College for the year 2002 were as follows:

- Incoming Capacity of 6 MVA.
- Time Of Use Tariff.
- Peak Annual Maximum Demand of 5,1 MVA (in February and March).
- Annual Electricity Bill of approximately R 4,18 million.
- Demand Charges account for approximately 40% of total electricity costs in summer.

Electricity is purchased from the Durban Electricity Department. The University purchases electricity at 11kV from the municipality and this goes through an 11kV/6.6 kV transformer and then fed into a 6.6 kV ring main system. A portion of the reticulation diagram of the ring main is shown in Fig 5.3.

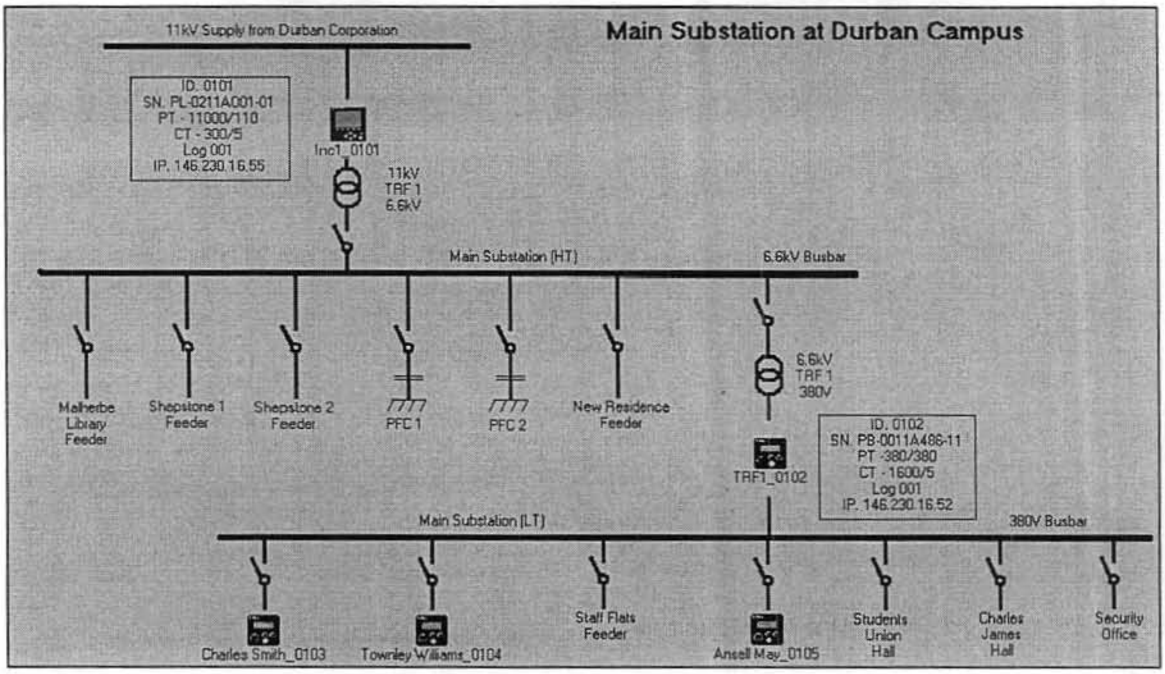


Fig 5.3: Reticulation Diagram showing the Main Incomer for Main Campus

5.2. Results of the Energy Audit

5.2.1. Results of Walk-Through Audit on the Main Campus

The emphasis of the initial energy audit was electrical energy but this focus grew to include mechanical energy. The loads that currently contribute to the Main Campus's incomer can be broadly categorised as follows:

- Commercial Buildings (Offices and Lecture Theatres).
- Industrial Loads (Air-conditioning Plants).
- Residential Loads (Student Residences).

The initial task was to conduct an energy audit to identify large loads, separate these loads into the broad categorisation above and to identify the controllable loads. The major loads appear in Table 5.2.

MAJOR LOADS	PEAK CAPACITIES	CATEGORY
Internal Lighting Load	1 999 kW	Commercial
Unitary A/C Equipment	1 696 kW	Industrial
North Core chilled water system	1 017 kW	Industrial
South Core chilled water system	245 kW	Industrial
Boilers in Residences	672 kW	Residential
Other A/C Plant	466 kW	Industrial
Other Loads	1450 kW	All

Table 5.2: Installed Capacities of Large Loads

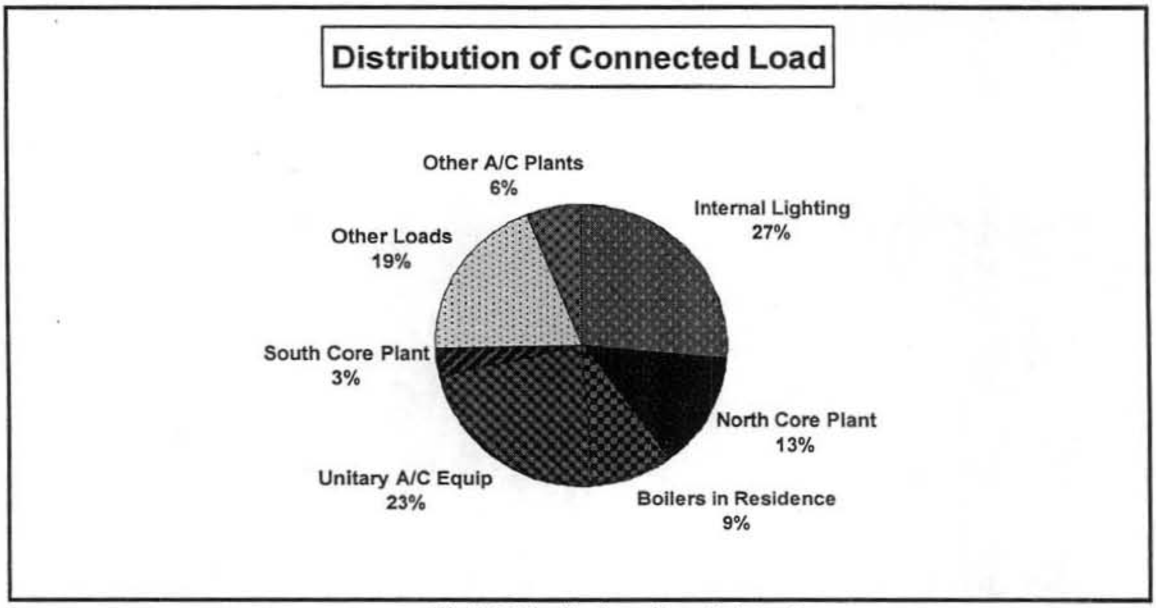


Fig 5.4: Distribution of Installed Loads

Fig 5.4 graphically illustrates the data in Table 5.2. From Fig 5.4 it can be seen that the total connected air-conditioning load is 3 424 kW. This accounts for approximately 45% of the total connected load. With the climate being subtropical, the air-conditioning requirements are quite demanding. The internal lighting load accounts for 27% of the connected load. The air-conditioning load is analysed in greater detail in Chapter 6 and a lighting case study is examined in Chapter 7 to illustrate the potential for energy efficient lighting on the main campus.

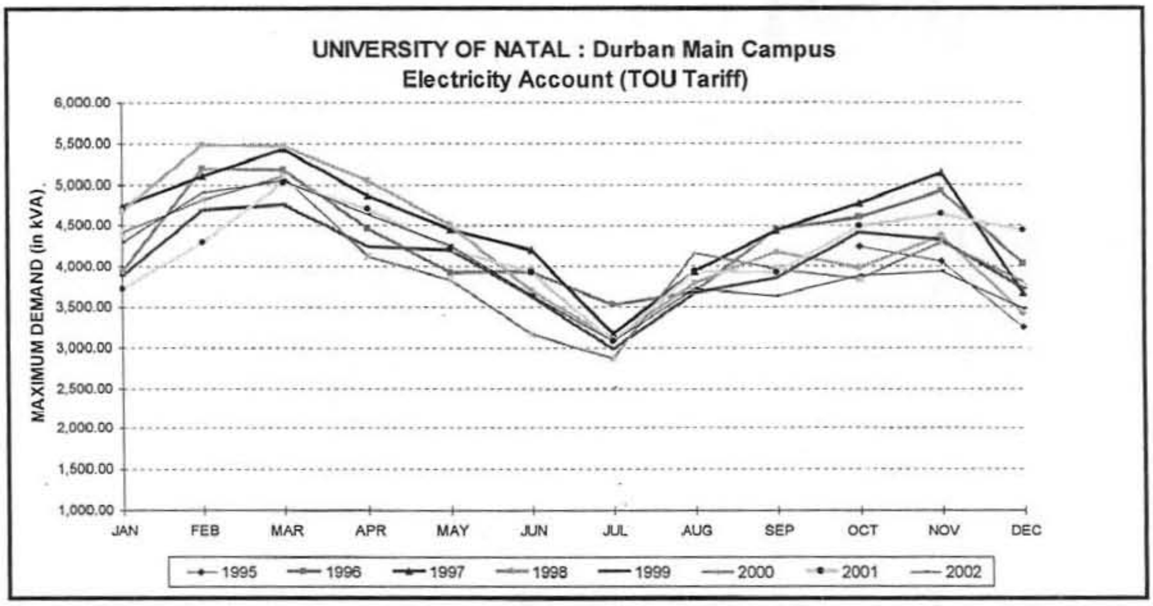


Fig 5.5: Annual Maximum Demand Trends for Main Campus

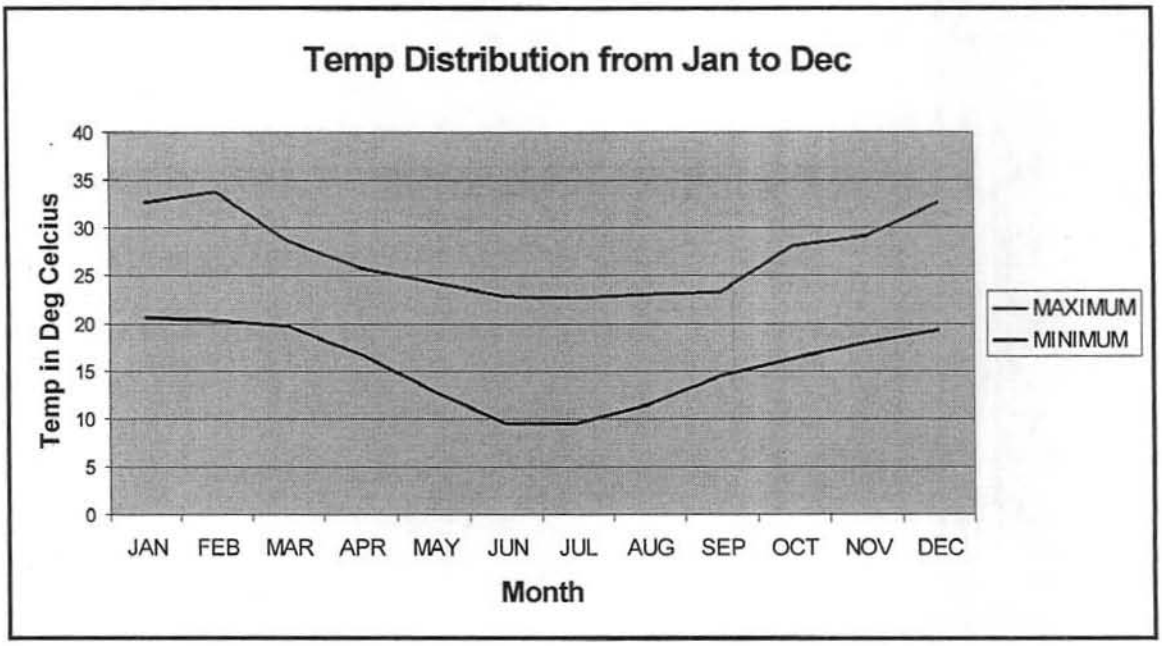


Fig 5.6: Annual Temperature Distribution for the Durban Area

Comparing the maximum demand trends and the average temperature levels recorded during the year yields Figs 5.5 and 5.6 respectively it is seen that their contours are very similar. University policy states that the university does not fulfill the heating requirements. Certain staff members and students in residences have space heaters in their offices or rooms. There are currently no guidelines on what equipment is appropriate for fulfilling these heating requirements. There is potential to reduce energy consumption in winter by instituting and implementing guidelines on energy efficient heaters, especially in the residences.

5.2.2. Definition of Energy Indices

Due to the University of KwaZulu-Natal being an eclectic mix of buildings that reflect the different architectural trends of the time periods in which they were built, a scientific method that allowed for the comparison of two different buildings was needed. For this reason, certain energy indices were defined. The variables and indices that were used are defined below:

Total Assignable Floor Area: Floor area in any building or structure, except separate parking structures, that can be used by the building occupants to carry out their function

Non-assignable Area: Floor area in any building or structure that is used for:

- Public corridors, lobbies, stairways, elevators (floor openings), and other general-circulation facilities. Included are janitor closets and other specialized custodial facilities, including storage facilities that are used only for building maintenance.
- Heating, ventilation, air conditioning, electrical, and other such utility rooms or spaces required for building operation.
- Pipe shafts and duct chases.
- Public toilets.

Gross Floor Area: The sum of the floor areas of the building included within the outside face of the exterior walls for all stories or areas that have floor surfaces. The sum of the total assignable floor area and the non-assignable floor area will total the gross floor area.

Summer and Winter: The summer and winter months indicated in the analysis are the summer and winter months as defined in the TOU tariff. In South Africa, the system peak occurs in the winter months and the energy and demand charges are typically higher during these months to encourage users to manage their energy consumption. For the purposes of clarity, the tariff defines the WINTER months as June, July and August and the remaining months are regarded as SUMMER months.

Total Energy Cost per Assignable Square Meter per Year: (R/m^2): Due to the variation in assignable floor area for the different buildings it was decided to use the above index to reduce the energy usage to a common base so that energy usage comparisons could be made for the different buildings. Since the bulk of all energy consumption occurs in the assignable floor area, this quantity was used in the calculation. The index was calculated, as shown in equation 5.1, over the year to incorporate seasonal changes and occupation variations.

$$\frac{\sum_{Year} kWhCosts}{AssignableFloorArea} \tag{5.1}$$

Demand Cost per Assignable Square Metre per Year (R/m^2): Similar calculation as Total Energy Cost per Assignable Square Meter per Year, except that demand is used in the calculation (equation 5.2) instead of energy.

$$\frac{\sum_{Year} DemandCosts}{AssignableFloorArea} \tag{5.2}$$

Average Energy Used per Assignable Square Metre per Year (kWh/m2): Similar calculation as Total Energy Cost per Assignable Square Meter per Year, except that energy usage is used in the calculation (equation 5.3) instead of energy costs.

$$\frac{\sum_{Year} kWhConsumed}{AssignableFloorArea} \tag{5.3}$$

5.2.3. Energy Analysis of Durban Main Campus

Using the energy indices defined above, an analysis was done of the energy consumption patterns of the Durban Main Campus. As can be seen from Table 5.3 below, the bulk of the energy is used during the summer period. This is to be expected since the summer months constitute nine months out of a twelve-month billing period. The highest demand and the maximum active energy consumed occur in March due to the high air-conditioning loads experienced during this month. The demand cost is highest during the summer months, again as expected due to the climate. The average energy cost is 19.99 cents per kWh consumed for the year.

The demand cost accounts for only 33.55 % of the total energy cost in winter versus the 39.2 % in summer. This indicates a potential opportunity to control load in summer and minimise the demand costs, thereby minimising the total energy costs. More analysis into this will be done later on in this chapter.

Durban Main Campus Energy Indices		
Total Assignable Floor Area	189 231 m^2	
Total Gross Floor Area	167 721 m^2	
Energy Use Indices		
Specific Energy Index	**Unit**	**Indices**
Annual Energy Consumption	kWh	20,905,916.00
kWh Used in Summer	kWh	16,160,524.00
kWh Used in Winter	kWh	4,745,392.00
Maximum Monthly Energy Consumption	kWh	2,096,285.00
Minimum Monthly Energy Consumption	kWh	1,417,122.00
Mean Monthly Energy Consumption	kWh	1,742,159.67
Maximum Monthly Demand	kVA	5,051.16
Minimum Monthly Demand	kVA	3,079.42
Mean Monthly Demand	kVA	4,042.96
Demand Cost as a % of Total Energy Cost (Summer)	%	39.20%
Demand Cost as a % of Total Energy Cost (Winter)	%	33.55%
Average Summer Load Factor		0.62
Average Winter Load Factor		0.64
Average Annual Energy Cost	c/kWh	19.99
Annual Energy Cost	R	R 4,178,924.92
For the purposes of clarity the WINTER months are June, July August and the remaining months are regarded as summer months as per the tariff		

Table 5.3: Energy Indices for Main Campus

Energy load profiles during the year 2002 are given below and discussed.

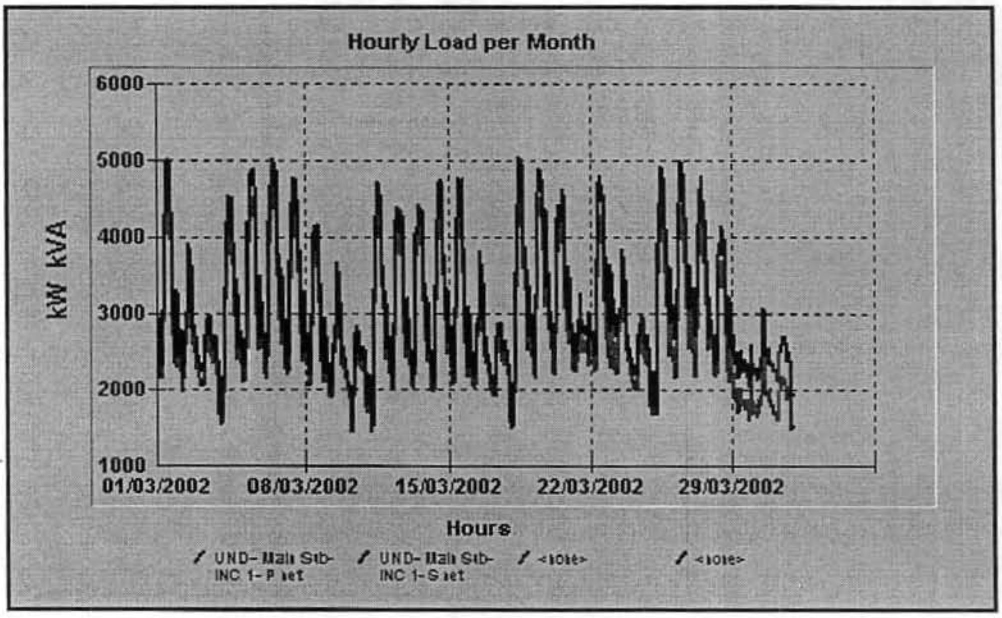


Fig 5.7: Main Incomer 2002 Summer Profile

Fig 5.7 shows the energy profile for the main incomer for the month of March 2002. This is the month that the campus historically experiences the highest demand in the year. This corresponds to the period when the temperature and relative humidity is at its maximum for the Durban area, which again implies air-conditioning as the main offender.

A typical summer week is shown in Fig 5.8 below:

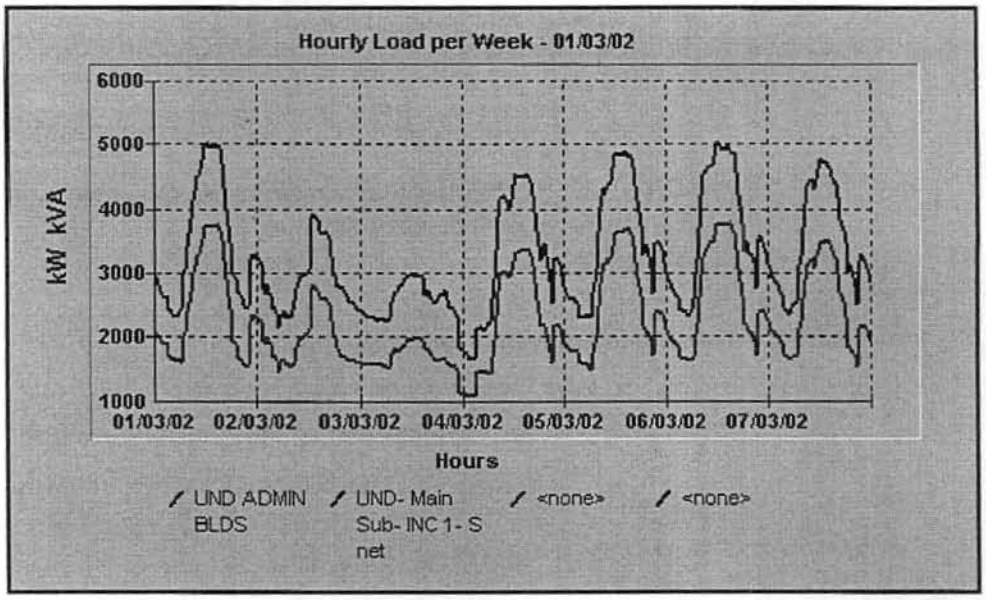


Fig 5.8: UND Main Incomer Summer Week Profile

Fig 5.8 shows that the high demand is maintained fairly constantly during the week. Note that the 2nd and 3rd March in the above profile is Saturday and Sunday respectively.

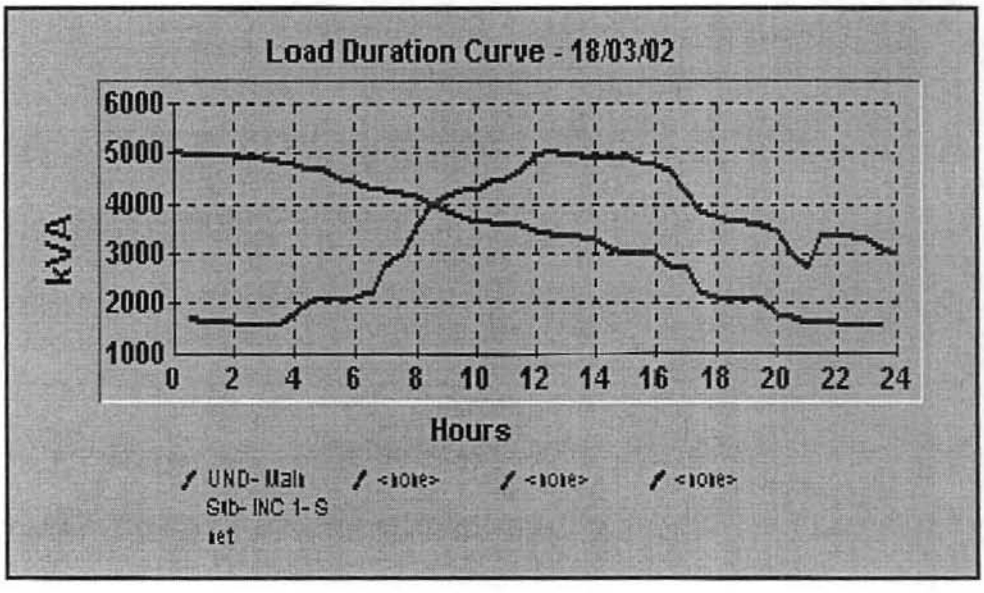


Fig 5.9: Summer Load Duration Curve

The load duration curve for a summer day is shown in Fig 5.9. To load shed or control the load during this period requires control to be implemented for a six-hour period to keep the demand at or below 4.5 MVA.

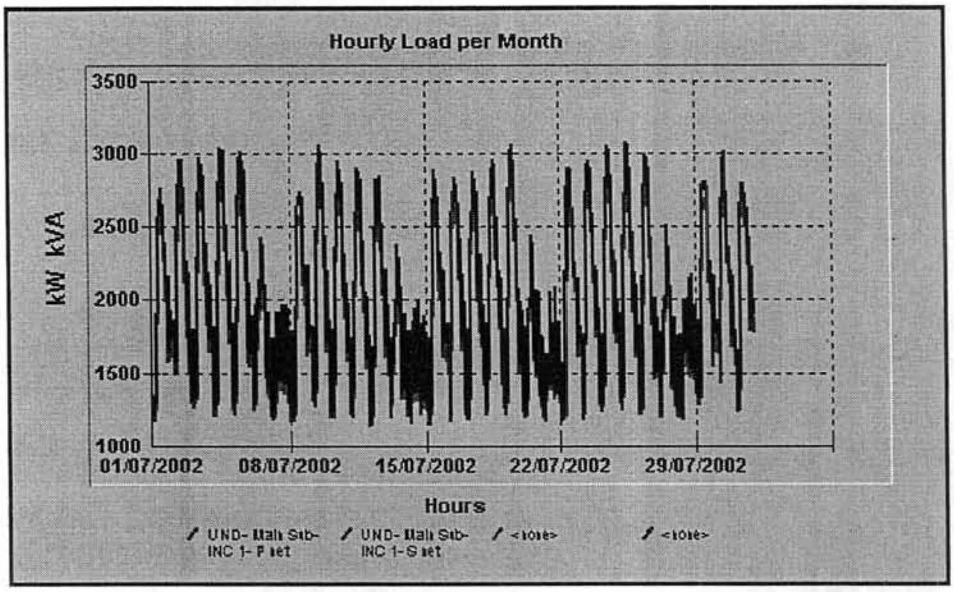


Fig 5.10: Main Incomer Winter Load Profile

Fig 5.10 shows the load profile for a typical winter month. From an operational point of view, the administration departments would have been operating normally during this period but the students would typically be on vacation during this time (July and part of August). The University does operate a winter school during this period but the usage of the lecture venues and residences are low during this time. The profile for the month of August would give a more accurate picture of the winter energy consumption during normal operation. This is shown in Fig 5.11 below:

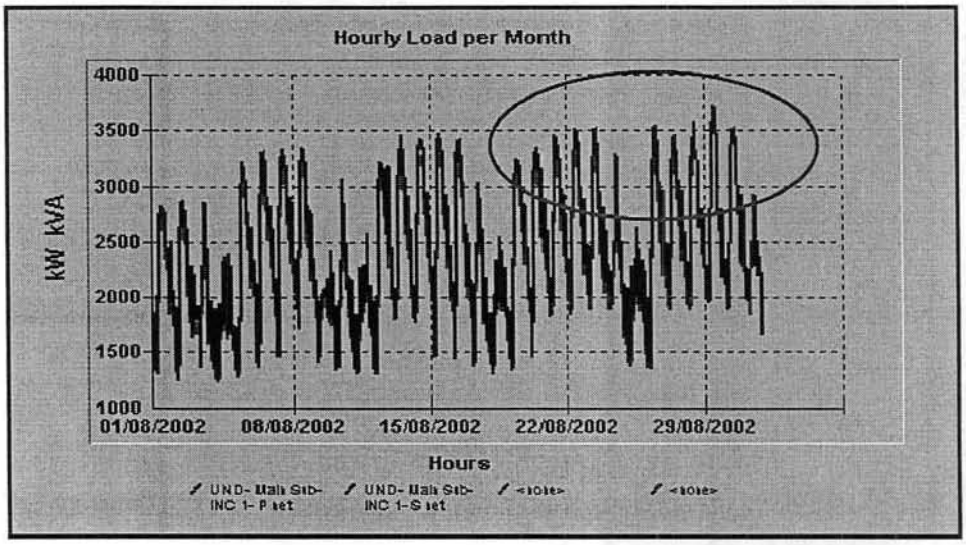


Fig 5.11: Winter Monthly Load Profile

The difference in demand between July and August is approximately 300 kVA as shown by the red circle is Fig 5.11. Graphs for a typical winter week (Fig 5.12) and winter day (Fig 5.13) are shown below:

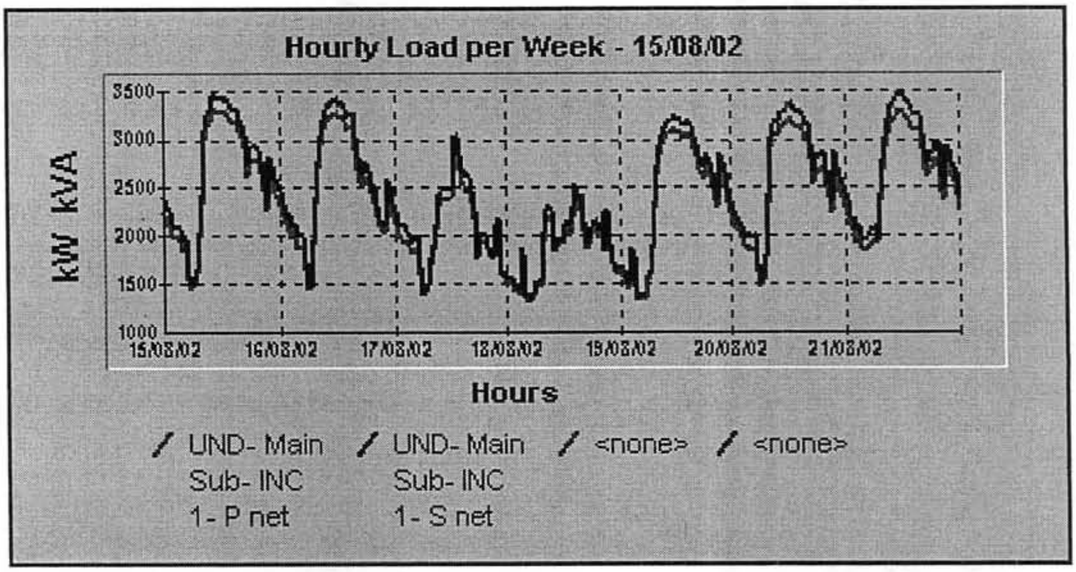


Fig 5.12: Winter Weekly Load Profile

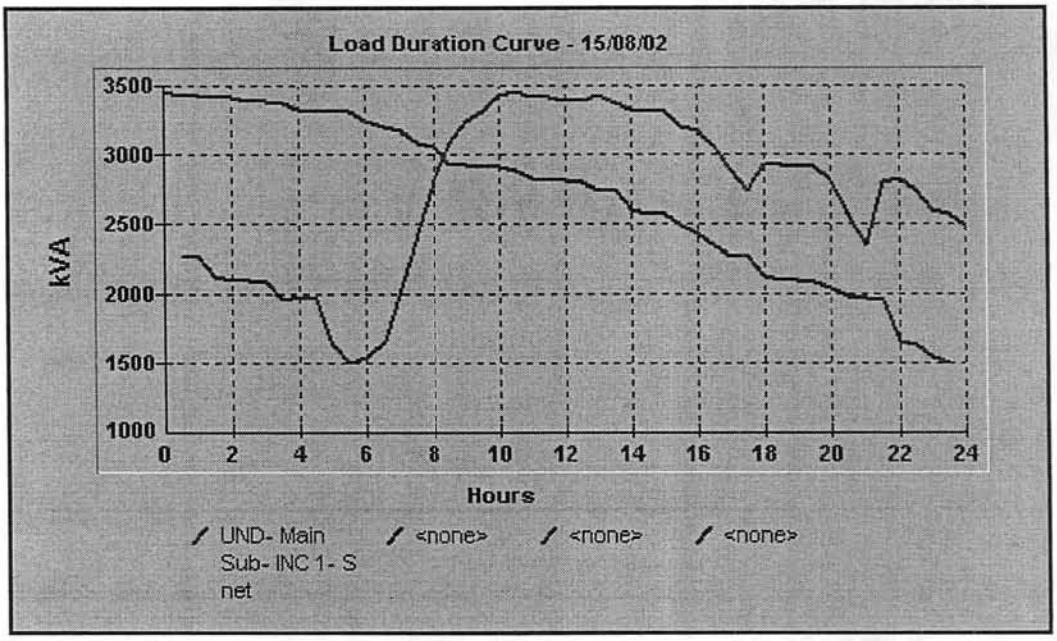
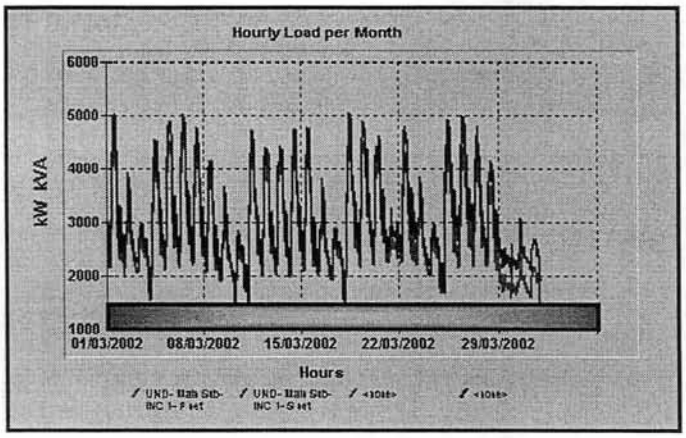


Fig 5.13: Winter Daily Load Profile



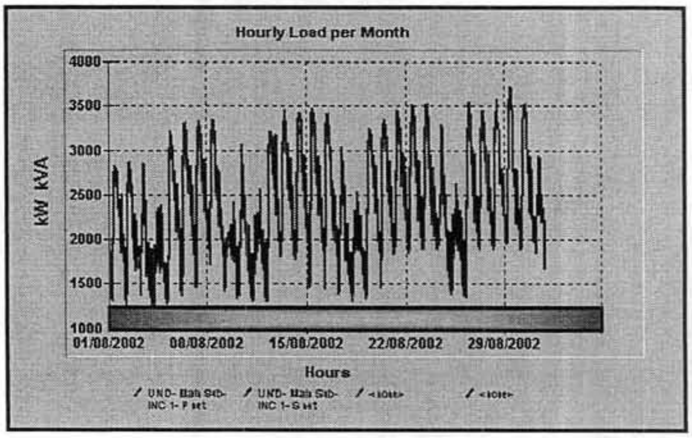
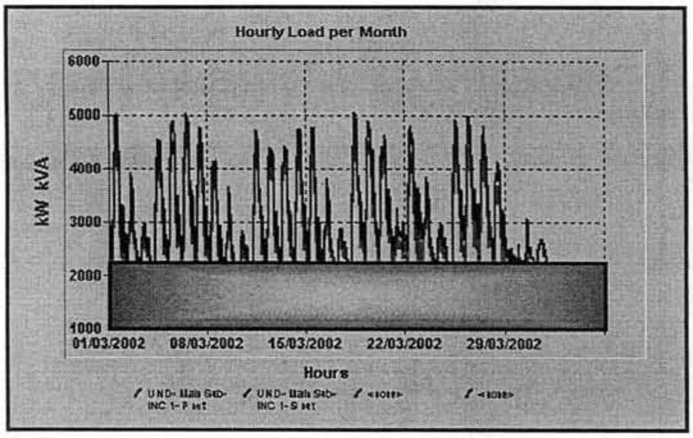


Fig 5.14: Baseload in Summer Monthly Load Profile

Fig 5.15: Baseload in Winter Load Profile Monthly

From Figs 5.14 and 5.15 above, it can be seen that there is a baseload that fluctuates between 1483 kVA and 1270 kVA in summer and winter respectively. Careful inspection of these graphs show that the baseload values quoted above typically occur during the weekend. By inspecting the average baseloads during the week the following trends are seen:



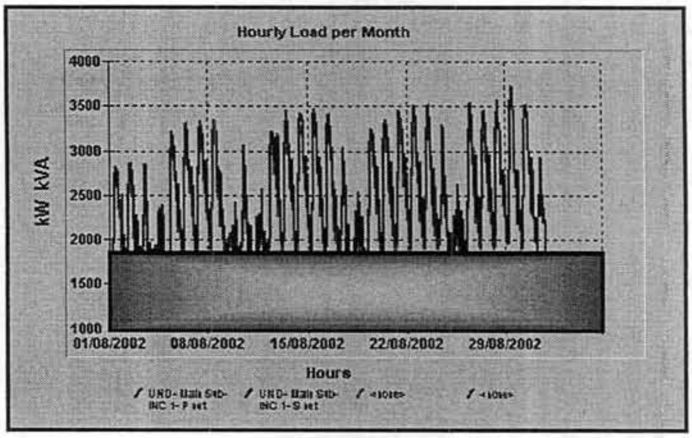


Fig 5.16: Baseload in Summer Monthly Load Profile

Fig 5.17: Baseload in Winter Monthly Load Profile

Upon inspection of Figs 5.16 and 5.17 it can seen that during the week in summer the average baseload is 2250 kVA in summer and 1830 kVA in winter. The loads that should be operational during the offpeak hours would be the thermal storage systems, security lighting and some residential loads. Further inspection of the energy consumption of each building on campus will determine if there are any unneccesary loads being energised during the offpeak hours. Note that the effect of a high baseload would be a higher cumulative offpeak energy cost and the effect on the demand will be nil as the maximum demand typically occurs during the day when all the loads should or would be energised anyway. The cumulative impact of the academic and administration buldings will now be examined in more detail.

5.2.4. Cumulative Impact of Academic and Administration Buildings

Aggregating the energy consumption of all the administration and academic buildings together and plotting this aggregated curve against the demand curve for the main incomer results in the graphs below in Fig 5.18 and Fig 5.19. The buildings that were chosen as administration and academic buildings are listed below:

- George Campbell.
- Denis Shepstone.
- Science Lecture Theatre.
- Durban Centenary Building.
- Francis Stock.
- Desmond Clarence.
- Chemical Engineering.
- EG Malherbe Library.
- Electrical Engineering.
- Howard College.
- Memorial Tower Building.
- Mechanical Engineering.
- Chemistry Building.
- TB Davis Lecture Theatres.
- Applied Chemistry.

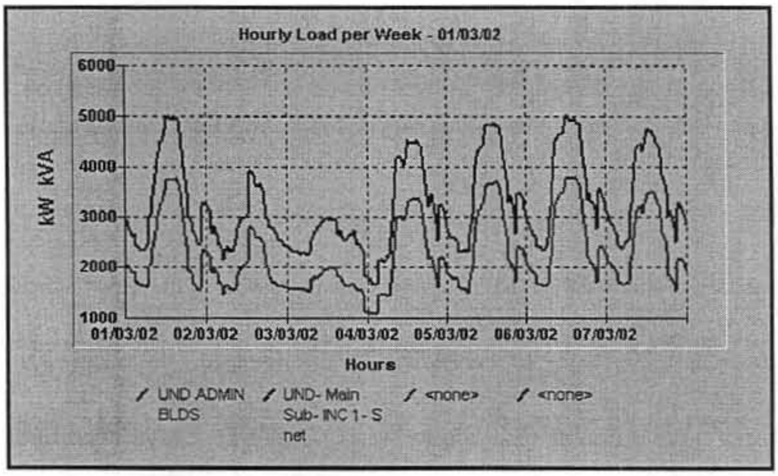


Fig 5.18: All Administration Buildings Aggregated vs. Total Incomer Consumption (Summer)

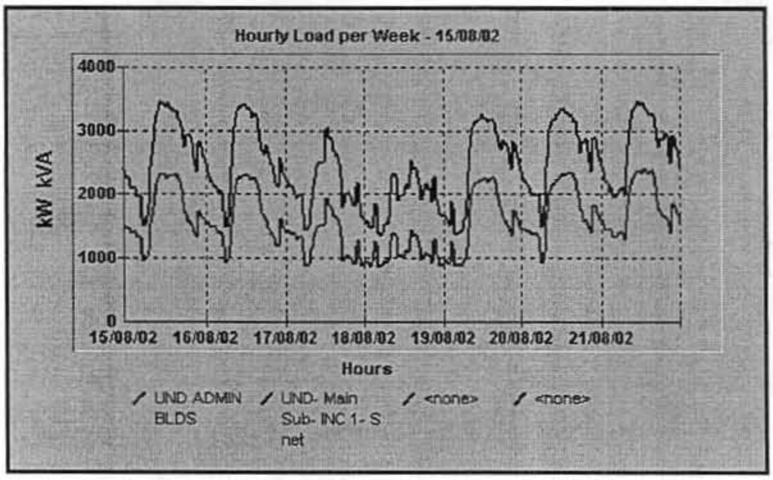
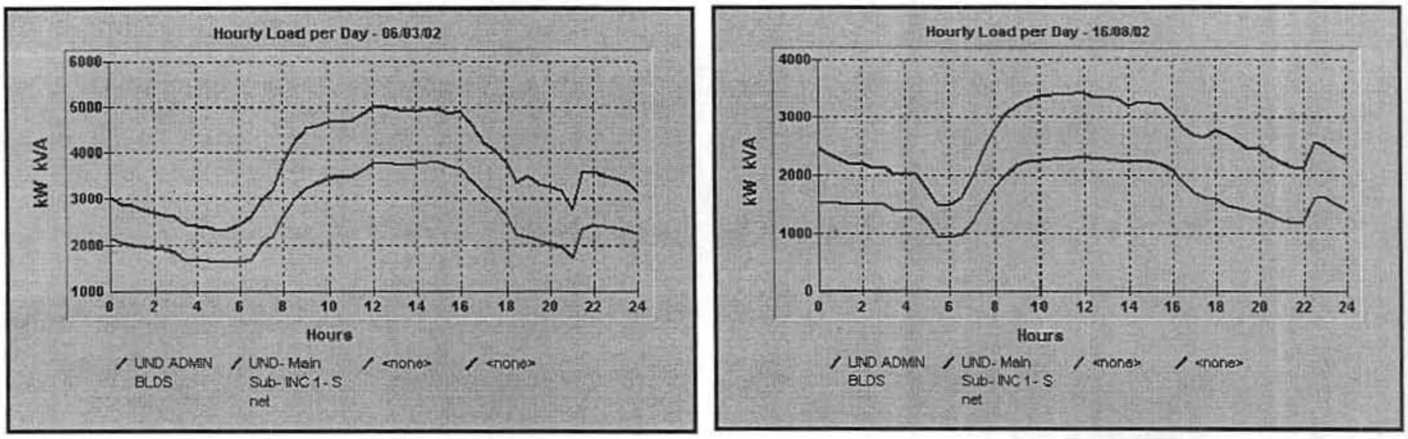


Fig 5.19: All Administration Buildings Aggregated vs. Total Incomer Consumption (Winter)

It can be seen from Figs 5.18 and 5.19 that the energy consumption pattern exhibited by the administration and academic buildings closely influence and resemble the energy consumption pattern of the main incomer.



Figs 5.20 and 5.21: Daily Load Profile of Main Incomer and Administration Buildings

This is further confirmed by inspecting the aggregated profile of the administration and academic buildings versus the main incomer profile for a random single day in summer and winter, as shown above in Figs 5.20 and 5.21. The above observation is also a logical one since the bulk of the energy consumption is due to the above-mentioned buildings. The difference between two profiles would then be the consumption of the residences and sports facilities at the university.

Therefore if endeavours were made to minimise the energy costs of the administration and academic buildings, a substantial impact would be made on the minimisation of the main incomer energy costs.

5.2.5. Results of Audit of Each Building/Feeder

In 2000 a state-of-the art (R3.2 million), web-based, Energy Management System (EMS) was installed at the University of KwaZulu-Natal, as part of the esATI Energy Management Program. The system provides detailed energy consumption patterns for the areas that it meters. Meters were installed on all the transformers within the ring main system on the Main Campus. An overview of this EMS is shown in Appendix C as well as the reticulation diagram for the ring main.

An analysis of the energy use of each of the metered areas with the results obtained from the walkthrough audit is given in Appendix D. The maximum demand used in the calculations in Appendix E for each feeder was the demand that that particular feeder contributed to the main incomer maximum demand. An example would be as follows: if the maximum demand for the main incomer occurred at 14h00 on 28th March 2002, then the demand value of each feeder at

14h00 on 28th March 2002 was used as the demand in the cost calculations. The summary of this analysis is shown below with some pertinent observations. Appendix D and Appendix E has the feeder analysis in greater detail.

5.2.6. Audit Result Summary

The feeders were analysed and opportunities for savings have been identified. This section will summarise the results of this analysis, paying particular attention to the energy/cost saving opportunities. A comparison of the some of the energy indices defined above will also be carried out. The first summary shows savings that can be realised through a reduction in baseload. Note the figures quoted below indicate the baseload that is present due to non-critical loads being energised. This in no way impacts on the security lighting, which is regarded as a critical load at night. This is summarised in Table 5.4.

Name of Feeder	Base Load Reduction (Summer)	Base Load Reduction (Winter)	Load Shifting between 10h00 and 16h00 (Summer)	Load Shifting between 10h00 and 16h00 (Winter)
Electrical Engineering	100 kW	50 kW	50 kVA	30 kVA
Biology	30 kW	30 kW	10 kVA	10 kVA
Durban Centenary Building	40 kW	25 kW	40 kVA	20 kVA
Chemistry (incorporating Chemical Engineering Applied Chemistry)	120 kW	100 kW	120 kVA	60 kVA
Francis Stock	25 kW	20 kW	30 kVA	30 kVA
Howard College	0 kW	0 kW	0 kVA	0 kVA
Maths/Physics	80 kW	50 kW	80 kVA	50 kVA
Mechanical Engineering	50 kW	45 kW	0 kVA	0 kVA
Memorial Tower Building	20 kW	10 kW	50 kVA	30 kVA
Science Lecture Theatre	0 kW	0 kW	0 kVA	0 kVA
Denis Shepstone (incorporating TB Davis Lecture Theatres)	220 kW	200 kW	40 kVA	30 kVA
TOTAL	**685 kW**	**530 kW**	**420 kVA**	**260 kVA**

Table 5.4: Energy Conservation Opportunities

By simply reducing the baseload, which is an intervention that will require minimal costs, as it will be an awareness issue; conservative estimates show that 1.286 MWh of off-peak electricity can be saved. This translates into a cost saving of R 100 233.58 per annum in 2002 energy costs.

This is a 2.5% saving on total energy costs just by making the building occupants more aware of the benefit of energy conservation. The input costs required for this, as mentioned above, will be low. This reduction on energy usage also has environmental benefits, through reduced emissions due to power not being generated. The emission savings are given in Table 5.5 below:

Overall Emission Savings Due to Reduced Baseload			
Carbon Dioxide	892 kg/MWh	1,147,379.60	kg
Nitrous Oxide	6 kg/MWh	7,717.80	kg
Sulphide Oxide	7.2 kg/MWh	9,261.36	kg
Particulate Matters	0.7 kg/MWh	900.41	kg
Water	1.23 Litre/kWh	1,582,149.00	litres

Table 5.5: Emission Savings due to Reduced Baseload

For the load shifting opportunities, Table 5.4 indicates that 420 kVA and 260 kVA can be shifted in summer and winter respectively. Working on a conservative estimate of 250 kVA in summer and 150 kVA in winter reveals that R 77 046.74 per annum (in 2002 costs) can be saved through reduced demand. The cost to implement this will need to be investigated further. The loads that have been selected as potential load shifting opportunities are the unitary air-conditioning equipment. This load can be categorised as necessary and can be grouped and switched off for short periods (eg. ten minutes in a thirty minute demand window) without adversely affecting the environment.

Table 5.6 below lists some indicators that have all been reduced to some common denominator, eg. energy consumption as a function of assignable floor area, to enable one to make a comparison of the building performance. From this one would be able to see which building consumes more energy than another equivalent building with the same utilization characteristics.

The Francis Stock building, which coincidentally houses the offices of the University executive management, has the highest energy cost and demand cost per square metre. This building also has the highest energy cost (c/kWh). It is sometimes easier to compare these indicators in graphical form. These are shown in Figs 5.22-5.24.

Audit Results for Academic and Adaministration Buildings							
Feeder	Total Energy Cost 2002 in Rands	% Contribution to Total Cost	Annual Energy Consumption kWh	Total Energy Cost per Assignable Area 2002 R/sq metre/yr	Demand Cost per Assignable Sq Metre R/sq metre/yr	Annual Energy Cost in c/kWh	Average Energy Used per Sq Metre kWh per Sq Metre in 2002
Electrical Engineering	R 207,650.97	4.97%	1,001,115.00	R 24.86	R 16.04	20.74	188.38
Biology 1	R 122,659.42	2.94%	668,624.00	R 10.70	R 3.62	18.35	58.32
Centenary Building	R 71,103.90	1.70%	319,946.00	R 12.44	R 5.48	22.22	55.96
Chemistry	R 317,033.66	7.59%	1,461,172.00	R 31.72	R 13.34	21.70	146.20
Francis Stock	R 107,407.84	2.57%	390,014.00	R 49.23	R 25.40	27.54	178.76
Howard College	R 124,951.52	2.99%	660,903.00	R 20.79	R 7.83	18.91	109.94
Mechanical Engineering	R 139,621.65	3.34%	571,820.00	R 20.70	R 9.86	24.42	84.80
Maths/Physics	R 144,982.42	3.47%	665,298.00	R 20.96	R 8.90	21.79	96.20
Memorial Tower Bldg 2	R 119,372.76	2.86%	451,706.00	R 7.64	R 3.79	26.43	28.93
Science Lecture Theatres	R 109,039.41	2.61%	484,654.00	R 30.71	R 13.75	22.50	136.50
Shepstone	R 556,587.41	13.32%	2,772,308.00	R 16.50	R 6.20	20.08	82.20

Table 5.6: Energy Indices for Major Buildings/Feeders on Main Campus

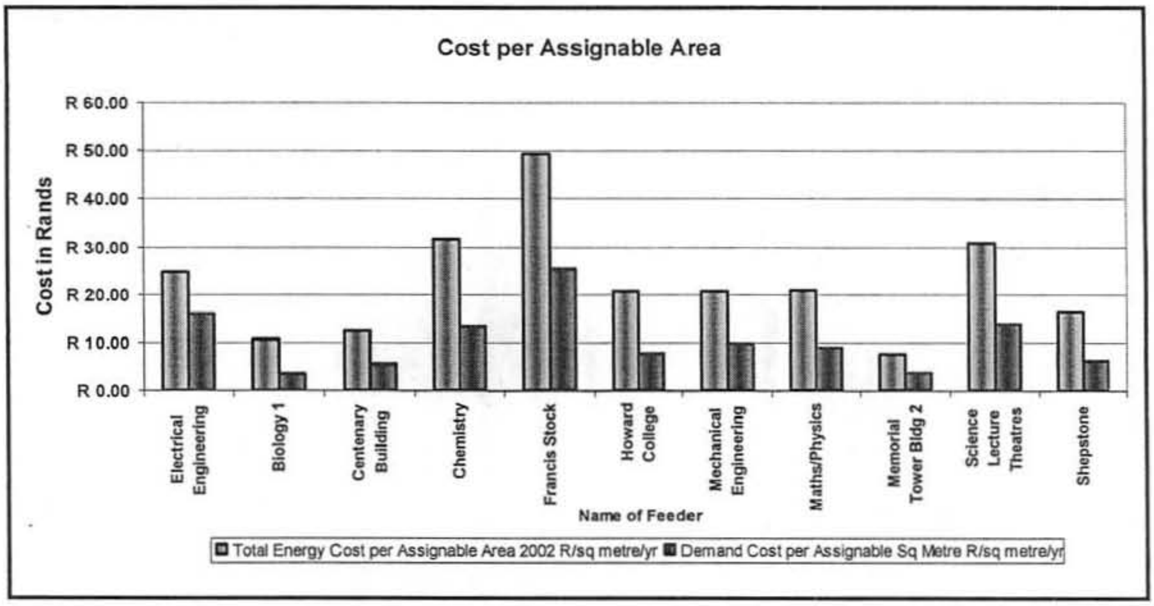


Fig 5.22: Graphical Representation of Cost per Assignable Area Annually for Admin Buildings

The costs for Biology 1, Howard College, Memorial Tower building, Science Lecture Theatres and the Shepstone building are not a true reflection as the cooling requirements for these buildings are met from elsewhere. Benchmarks need to be calculated for each building and energy and costs per assignable floor area need to be maintained within these benchmarks.

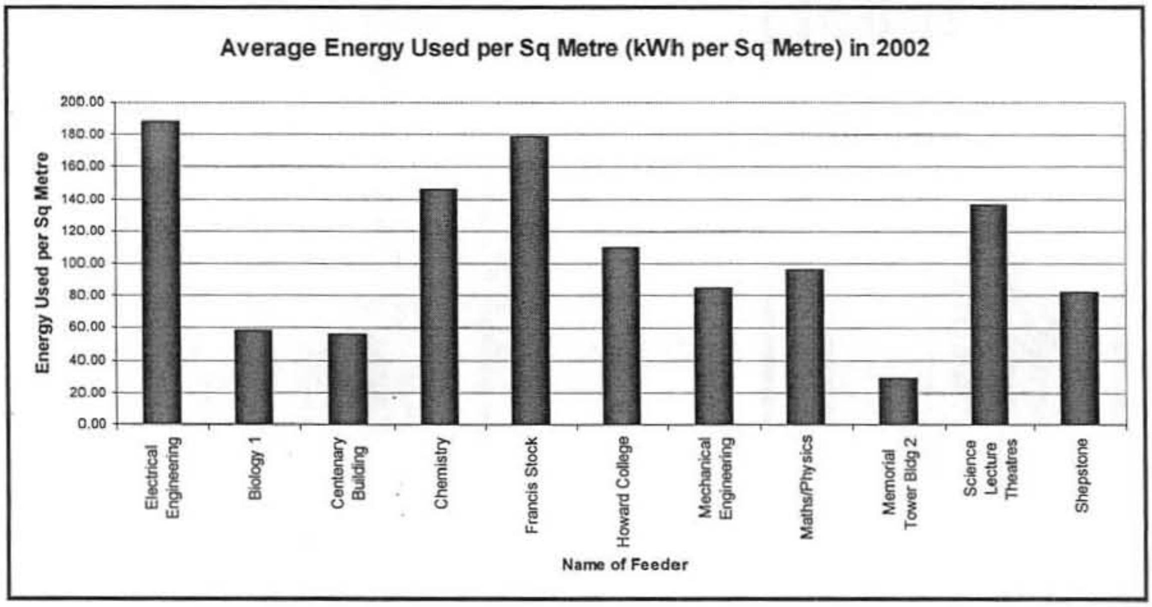


Fig 5.23: Graphical Representation of Average Energy Used per m^2 for Admin Buildings

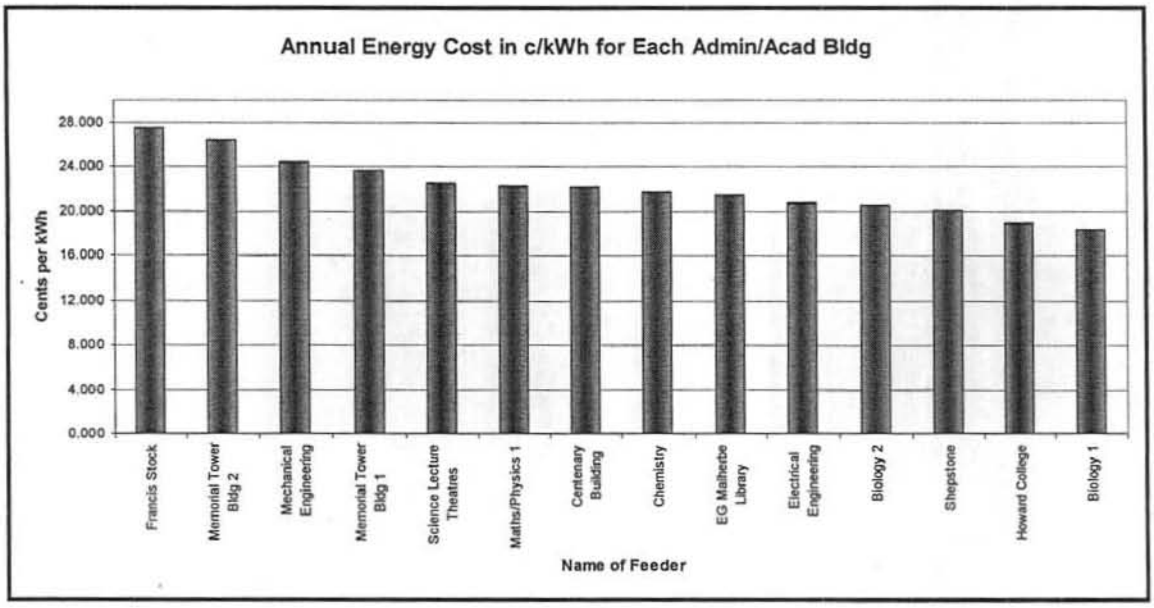


Fig 5.24: Graphical Representation of Annual Energy Cost in c/kWh for Admin Buildings

As can be seen from the above figures, there are variances between the costs and energy used per assignable floor area for each of the buildings analysed. Benchmarks need to be developed for each building as the building envelopes differ due to the University of KwaZulu-Natal being an eclectic mix of buildings that reflect the different architectural trends of the time periods in which they were built [57].

The residences are analysed in the next section.

5.2.7. Audit Results of the Residences

The University residences (Howard College) accommodate 2002 students.

Residences are grouped into two halls, namely Charles Smith Hall and Albert Luthuli Hall. Charles Smith Hall is comprised of 17 individual residences close to the main academic buildings, banks, shops and Medical School. Albert Luthuli Hall is comprised of the Cluster Residence and the six-storey Tower Residence. Situated on the western side of Howard College Campus, this complex is close to most sports fields and the Old Mutual Sports Centre.

All residences have access control, lounges and television rooms, intercom systems, call boxes and parking space. All students are accommodated in single rooms. All residences are self-catering while a dining facility is also available for students [58].

Since this study has been confined to the Main Campus, only the Charles Smith Hall group will be analysed. Table 5.7 shows the residences that make up the Charles Smith Hall as well as the student capacity for each residence.

Name of Residence	No of Students
Townley Williams Hall	114 students
Louis Botha Hall	142 students
John Bews	113 students
Florence Powell Hall	77 students
Ernest Jansen Hall	102 students
Charles James Hall	57 students
Ansell May Residence	158 students
Mabel Palmer Residences	95 students
Pius Langa Residence	252 students
JV Smit Residence	89 students
TOTAL STUDENTS	**1199 students**

Table 5.7: Student numbers in Residences

The major loads are the lighting loads, kitchens and hot water loads.

All rooms have 60 W incandescent light bulbs. There are two bulbs per room. There have been attempts to replace these bulbs with Compact Fluorescent Lights (CFLs) but this was not successful due to theft of the CFLs. Recommendations to get around this will be discussed in the concluding chapter.

The major loads in the dining/cooking facility are the stoves. The information obtained from the audit is shown below in Table 5.8.

Name of Residence	No of Stoves	Installed Capacity (kW)
Townley Williams Hall	13	78
Loius Botha Hall	16	96
John Bews	11	66
Jubilee Centre	0	0
Scully House	0	0
Florence Powell Hall	15	90
Ernest Jansen Hall	10	60
Charles Smith Hall	0	0
Charles James Hall	6	36
Ansell May Residence	16	96
Mabel Palmer Residences	18	108
TOTAL	**105**	**630 kW**

Table 5.8: Installed Capacity of Cooking Equipment in Student Dining Areas

The energy indices for the residences on the main campus are given in Table 5.9 below:

Results of Audit - Main Campus Residences		
Total No of Students	**1199**	
Energy Use Indices		
Specific Energy Index	**Unit**	**Indices**
Annual Energy Consumption	kWh	3,322,126.00
kWh Used in Summer	kWh	2,401,915.00
kWh Used in Winter	kWh	920,211.00
Maximum Monthly Energy Consumption	kWh	361,541.00
Minimum Monthly Energy Consumption	kWh	101,673.00
Mean Monthly Energy Consumption	kWh	276,843.83
Maximum Monthly Demand	kVA	582.00
Minimum Monthly Demand	kVA	189.00
Mean Monthly Demand	kVA	420.67
Demand Cost as a % of Total Energy Cost (Summer)	%	30.28%
Demand Cost as a % of Total Energy Cost (Winter)	%	24.73%
Total Energy Cost per Student per Yr	R/m^2	R 374.73
Demand Cost per Student per Yr	R/m^2	R 137.31
Average Energy Used Student in 2002	kWh/m^2	2770.75
Average Annual Energy Cost	c/kWh	17.68
Residence Annual Energy Cost	R	R 587,403.24
% Contribution to Total Annual Main Incomer Cost	%	14.06%
For the purposes of clarity the WINTER months are June, July August and the remaining months are regarded as summer months as per the tariff		

Table 5.9: Energy Indices of Student Residences

As can be seen from Table 5.9 above, the residences account for approximately 14% of the total energy cost on the Main Campus. The demand cost, as a percentage, is not as high as the academic/administration buildings. This is due to the fact that this is a residential type load and that the maximum demand for the residences would typically occur in the evening. The residences' contribution to the demand during the day was used in the calculations to get the energy indices. Examining the load profiles reveal the following:

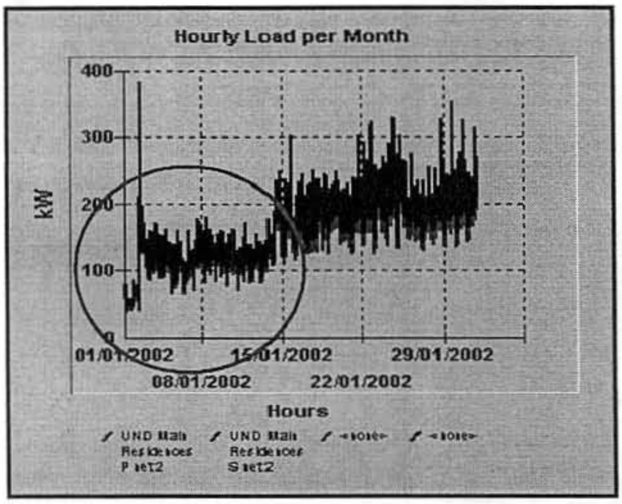


Fig 5.25: Monthly Load Profile for January

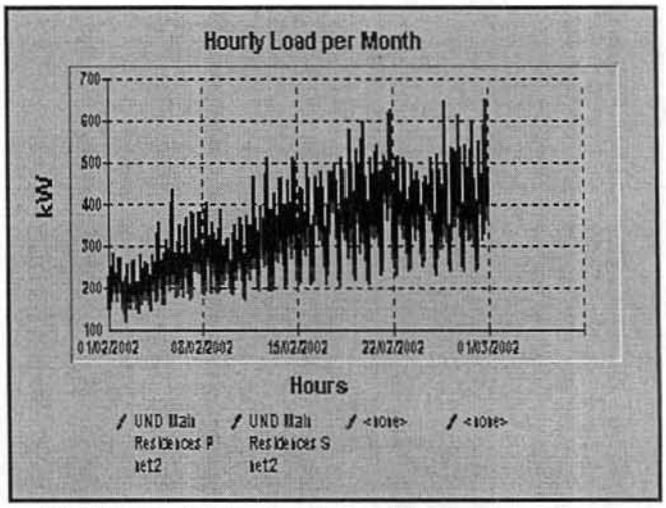
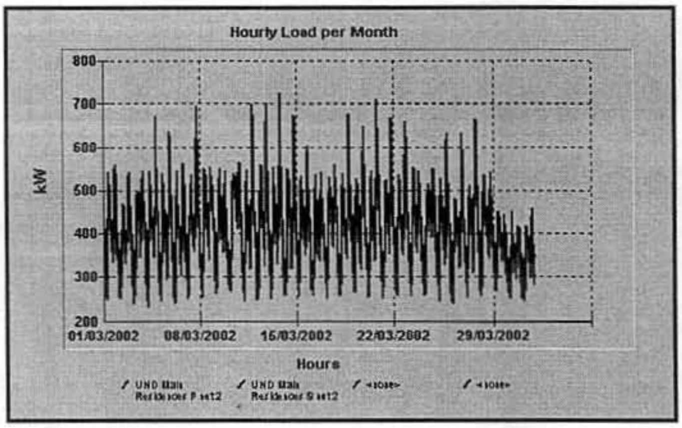


Fig 5.26: Monthly Load Profile for February

In January, the University is closed for the summer vacation, and the majority of the residences are vacant. The residences are sometimes used to accommodate conference attendees during the vacation, but this is very rare during January and is more likely to occur in July. Towards the end of February, students start to return to commence with their studies.

From Fig 5.25, it can be seen, that although the residences are vacant, there is still energy being consumed. Fig 5.26 shows the gradual increase of the profile as students return for the new academic year.

The summer and winter energy consumption in the residences have fairly small variances. This is illustrated in Figs 5.27 and 5.28 below. Unlike the academic/administration buildings, there is no air-conditioning load present here. Space heating is not provided in rooms, although occupants are allowed use their own space heaters.



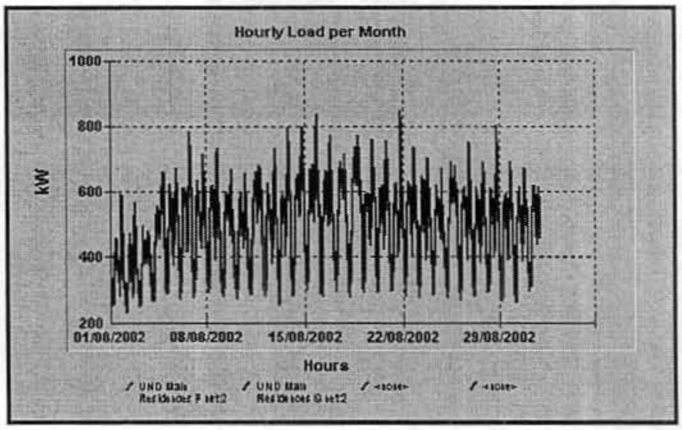


Fig 5.27: Residence Summer Profile (Monthly)

Fig 5.28: Residence Winter (Monthly) Profile

Fig 5.29 shows a typical weekly load profile in April 2002. The afternoon peak tends to dominate, as is usually the case with a residential load.

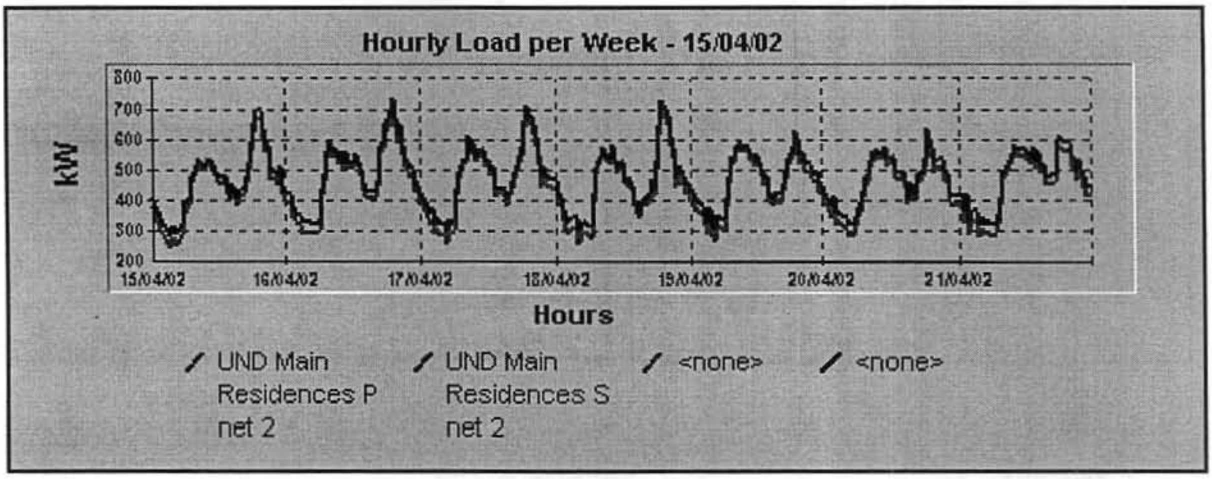


Fig 5.29: Residence (Weekly) Profile

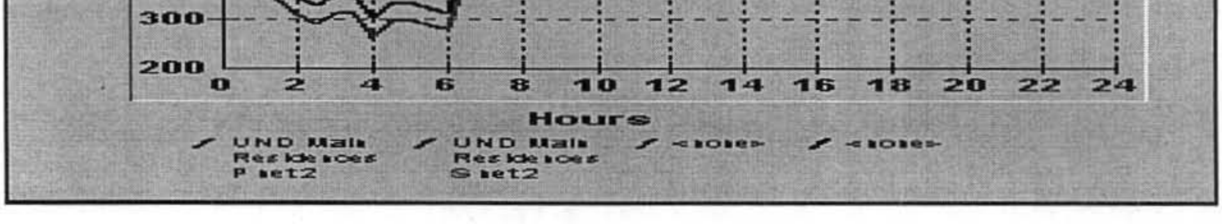


Fig 5.30: Residence Daily Profile

Examining the daily load profile in Fig 5.30 reveals that from 06h00 onwards the load picks up. This would be the time typically that the students are bathing and the boilers/geysers would then start to reheat the water. This load gradually decreases between 08h00 and 14h00. The load decreases by approximately 250 kVA during this time. From 16h00 to around 20h00 the load increases again due to bathing and cooking. From 20h00 the load starts to decrease until 22h00 where it picks up again for a short period. This is due to the hot water load. The hot water load is a potential controllable load. The installed capacities for the hotwater system are given in the Table 5.10 below.

Name of Residence	Electric In-Line Water Heaters /Boiler/Geysers	Equipment Rating
Townley Williams Hall (114 students)	2 x 48 kW in parallel	**96 kW**
Louis Botha Hall (142 students)	2 x 12 kW & 1 x 24 kW boilers; 4 kW geyser	**52 kW**
John Bews (113 students)	3 x 12 kW boilers; 3 kW geyser	**39 kW**
Jubilee Centre	4 kW geyser	**4 kW**
Scully Hall	2 x 3 kW geysers	**6 kW**
Florence Powell Hall (77 students)	2 x 24 kW Electric In-Line Water Heaters	**48 kW**
Ernest Jansen Hall (102 students)	2 x 24 kW Electric In-Line Water Heaters	**48 kW**
Charles James Hall (57 students)	12 x 3 kW boilers; 2 x 3 kW geysers	**42 kW**
Ansell May Residence (158 students)	1 x 50 kW boiler; 5 x 3 kW geyser	**65 kW**
Mabel Palmer Residences (95 students)	2 x 40 kW in parallel; 3 x 3 kW geysers	**89 kW**
Pius Langa Residence (252 students)	10 x 12 kW boilers; 5 x 3 kW geyser	**135 kW**
JV Smit Residence (89 students)	2 x 24 kW Electric In-Line Water Heaters	**48 kW**
TOTAL INSTALLED CAPACITY		**672 kW**

Table 5.10: Water Heating Equipment Register

With After Diversity Maximum Demand (ADMD), there is a potential to control 200 kW of load during the day. This can be achieved by managing this load so that it does not necessarily come on-line during 08h00 and 14h00 but is managed in conjunction with the other loads on campus, like the air-conditioning system. A detailed load shifting analysis (which is beyond the scope of this study) needs to be done to determine what the possible savings are.

Water usage is also a problem on the campus. A figure of 500 litres/student/day was quoted for one of the residences. Managing the energy usage for the water heating system will have also lead to lower water usage.

Chapter 6

Heating, Ventilation and Air-Conditioning

6.1. HVAC SYSTEMS

The Heating, Ventilating and Air-Conditioning (HVAC) system for a facility is the system of motors, ducts, fans, controls, and heat exchange units that deliver heated or cooled air to various parts of the facility. The primary purpose of the HVAC system in a facility is to regulate the dry-bulb air temperature, humidity and air quality by adding or removing heat energy [59].

The HVAC system is responsible for a significant portion of the energy use and energy cost in most commercial buildings. Many facilities have HVAC systems that were designed and installed during periods of low energy costs; these are often relatively expensive to operate because energy efficiency was not a consideration in the initial selection. In addition, many HVAC systems are designed to meet extreme load conditions for either very hot or very cold weather and are often poorly matched for average weather conditions that are ordinarily experienced. Thus improving the operation of the HVAC system provides many opportunities to save energy and reduce costs [60]. Before proceeding to audit the HVAC systems that are present on the main campus, a brief overview of how HVAC systems operate would be valuable. Particular attention will be paid to air-conditioning systems, as these are the dominant loads on the main campus. Space heating will not be discussed in this chapter as the university has a policy of not providing space heating on the Durban Main Campus. Appendix E has an overview of some of the theory behind air-conditioning systems.

6.2. Air-Conditioning Systems at the University of KwaZulu-Natal

There is currently a mixture of air-conditioning systems in operation on the Main Campus. These range from unitary equipment to central air-conditioning plants. A summary of the air-conditioning plants are given below:

- There is the North Core Plant. This is a Thermal Energy Storage (TES) system, which uses chilled water to extract heat from the building.
- There is also the Memorial Tower Building (MTB) system, which also uses chilled water, but there is no storage component here.

- The South Core plant is a smaller Thermal Energy Storage (TES) that is used to supply certain buildings on the southern part of the Main Campus.
- Mechanical Engineering and Francis Stock have Air-Cooled Chillers.
- George Campbell has a small Ice Plant.

6.2.1. North Core Plant

The largest TES system at the University of KwaZulu-Natal is referred to as the North Core Plant or Primary 1. The North Core is made up a tank that is used for partial storage, along with the chilled water equipment. The tank is housed underneath the front lawn of the Howard College Building, as shown in Fig 6.1.

Fig 6.1: Howard College Tank

The North Core Plant is made up of 3 water-cooled screw chillers, which chills water that is stored in a tank. The tank has a capacity of 2.742 million litres. The technical data for a single R134a Screw Compressor is given in Table 6.3. There are three such chillers. The three water-cooled TRANE RTHC chillers have a combined cooling capacity of 3 900 $kW_{refrigeration}$.

The thermal energy from this tank is used to provide cooling to the following areas:

- Denis Shepstone - coverage 11 000 m^2.
- Howard College - coverage 2 300 m^2 .
- EG Malherbe Library.
- Part of Chemistry coverage.
- Part of Chemical Engineering.

The bulk of the power for the North Core TES system is supplied from the transformer 1 and 3 in Denis Shepstone. The pump for the North Core TES system is supplied from the Howard College feeder. The energy indices for transformers 1 and 3 are given in Table 6.1 and Table 6.2.

The majority of the power for the North Core TES system is drawn from transformer 3. The energy cost for this feeder was R 337 770.92 in 2002. This accounted for 8.08 % of the total energy cost for 2002. The energy cost for transformer 1 was R 153 501.20 in 2002, and accounted for 3.67% of the total energy usage. The combined cost for these two feeders, excluding, the pump room was R 491 272.12 and accounted for 11.75% of the total energy cost. The load factors are low as can be expected from a TES system.

Results of Audit - Shepstone 1		
Energy Use Indices		
Specific Energy Index	**Unit**	**Indices**
Annual Energy Consumption	kWh	882,975.00
kWh Used in Summer	kWh	698,605.00
kWh Used in Winter	kWh	184,370.00
Maximum Monthly Energy Consumption	kWh	94,389.00
Minimum Monthly Energy Consumption	kWh	55,722.00
Mean Monthly Energy Consumption	kWh	73,581.25
Maximum Monthly Demand	kVA	142.65
Minimum Monthly Demand	kVA	124.44
Mean Monthly Demand	kVA	136.45
Demand Cost as a % of Total Energy Cost (Summer)	%	34.52%
Demand Cost as a % of Total Energy Cost (Winter)	%	36.04%
Average Summer Load Factor		0.27
Average Winter Load Factor		0.33
Average Annual Energy Cost	c/kWh	17.38
Building's Annual Energy Cost	R	R 153,501.20
% Contribution to Total Annual Main Incomer Cost	%	3.67%
For the purposes of clarity the WINTER months are June, July August and the remaining months are regarded as summer months as per the tariff		

Table 6.1: Shepstone Transformer 1 Energy Indices

Results of Audit - Shepstone 3		
Energy Use Indices		
Specific Energy Index	**Unit**	**Indices**
Annual Energy Consumption	kWh	1,634,208.00
kWh Used in Summer	kWh	1,383,062.00
kWh Used in Winter	kWh	251,146.00
Maximum Monthly Energy Consumption	kWh	216,055.00
Minimum Monthly Energy Consumption	kWh	72,742.00
Mean Monthly Energy Consumption	kWh	136,184.00
Maximum Monthly Demand	kVA	678.36
Minimum Monthly Demand	kVA	139.95
Mean Monthly Demand	kVA	423.99
Demand Cost as a % of Total Energy Cost (Summer)	%	48.77%
Demand Cost as a % of Total Energy Cost (Winter)	%	44.00%
Average Summer Load Factor		0.28
Average Winter Load Factor		0.32
Average Annual Energy Cost	c/kWh	20.67
Building's Annual Energy Cost	R	R 337,770.92
% Contribution to Total Annual Main Incomer Cost	%	8.08%
For the purposes of clarity the WINTER months are June, July August and the remaining months are regarded as summer months as per the tariff		

Table 6.2: Shepstone Transformer 3 Energy Indices

Design Parameter	Quantity	Unit
Design Cooling Capacity	1352	kW - Refrigeration
Power Input at Design Conditions	259.6	kW - Electrical
Number of Compressors per Chiller	1	
Chiller Flow Rate	32.3	Litres/sec
Chiller Pressure Drop	24	kPa
Chiller Temperatures Entering/Leaving	15 / 5	°C
Chiller Storage Capacity	348	litres
Condenser Flow Rate	70.1	Litres/sec
Condenser Pressure Drop	56.9	kPa
Condenser Temperatures Entering/Leaving	29.5 / 35	°C
Condenser Storage Capacity	263	litres
Power Supply	400 / 50 / 3	V / Hz / Ph
Control Voltage	110	V
Running Current at Design Conditions	424.4	A
Total of Motor Rated Currents (1)	488	A
Unit Starting Current (Star-Delta starting)	748	A

Table 6.3: North Core Equipment Ratings for Primary 1

This system is a partial storage system with the charging sequence programmed to operate in assist mode. The system is designed to operate in assist mode. The tank is fully charged at night and the thermal capacity is discharged during the day when the thermal load is required by the buildings. Assist mode is activated in the discharge cycle only. This mode is used to assist the tank in the event that the chilled water demand exceeds the flow capacity of the tank. Appendix E has the full charge/discharge philosophy.

The water in the tank is chilled to 5 ° C and pumped out to the thermal load requiring space conditioning. The return water should ideally have a return temperature of 15 ° C to ensure maximum storage capacity. This ensures a thermocline separates the chilled water from the heated water.

The assist mode is normally called upon for one of two reasons:

- To offset the consumption of chilled water from the tank so as not to exhaust the tank before the next charge cycle.
- So as not to exceed the maximum flow through the tank headers. To do so would create turbulence; this in turn would disturb the thermocline and result in the blending of the supply and return water within the tank.

The present chillers were replaced in 2000 due to the poor age and inefficiency of the previous chillers. This presented an opportunity to improve the efficiency of the system. An important component of the chiller system is the refrigerants used in the chillers. With respect to selecting the appropriate refrigerant to determine the chiller selection, it was concluded from initial investigations that either R134a or R717 (Ammonia) presented the best solutions. R134a is known to be the most "green" of the correct HCFC refrigerants. This refrigerant has worldwide acceptance, and most major commercial chiller manufacturers are designing chillers to operate on R134a. Ammonia is a refrigerant used in a wide range of industrial environments. When considering operating costs and efficiency, ammonia is an excellent refrigerant, which has been operating in proven chillers for decades. It is however toxic and flammable in certain concentrations. The eventual decision was to go with R134a, purely from a cost point of view. The capital costs of chillers that use ammonia as a refrigerant are approximately 30% more than those that use R134a as a refrigerant. This resulted in a longer payback period for the ammonia machines [64].

As the proposed chillers would be of similar capacity to the previous chillers, savings in electrical costs were realised due to the improved efficiencies of the new, more modern machines. The above solution satisfies the requirements of appropriate technology for ease of maintenance and low running costs, in that they are simple and durable with a degree of sophistication acceptable to the level of available expertise in the maintenance contractor market.

The present system was modelled taking into the thermal loads of the building and the following trends were observed. The electrical consumption of primary 1 is in Fig 6.12:

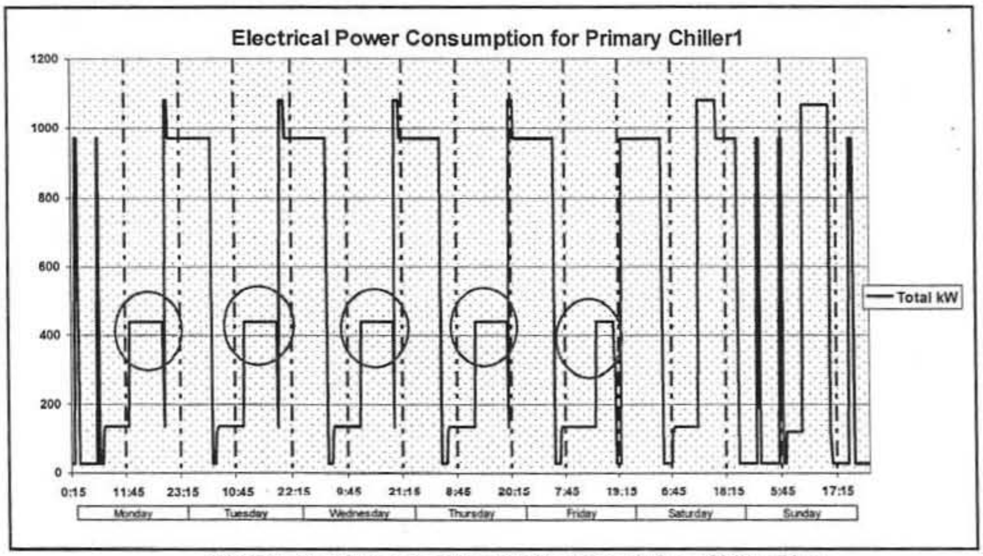


Fig 6.2: Simulated Electrical Profile of North Core Chiller Plant

The five red circles in Fig 6.2 indicate the time when the system is operated in assist mode and this is the time when the other controllable loads need to be controlled to ensure that the overall demand is maintained at a preset level.

Examining the chilled water profile of the tank reveals the following trend:

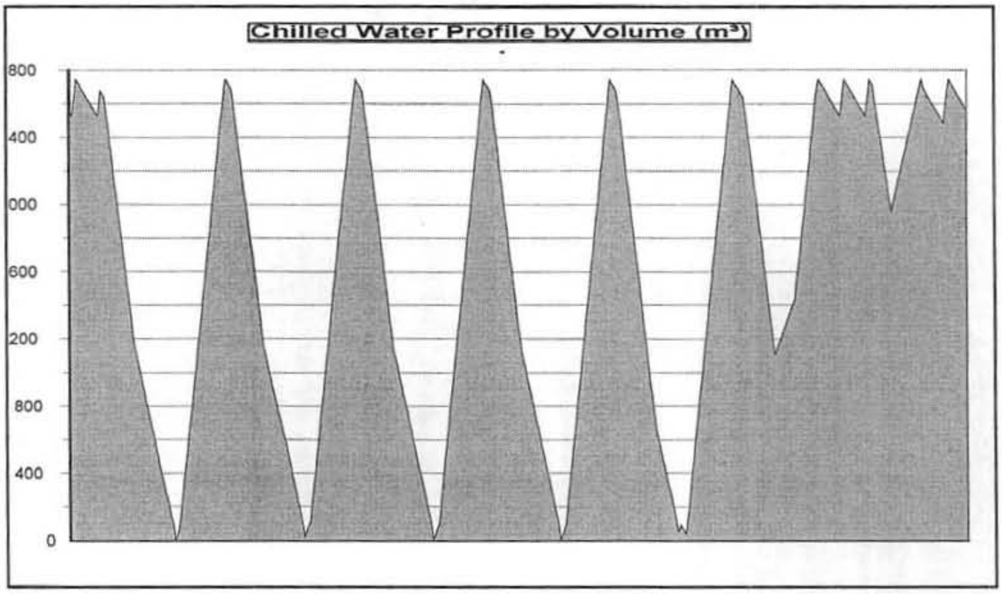


Fig 6.3: North Core Chilled Water Profile by Volume

Fig 6.3 is for a typical week. The individual graphs for each day is shown in Appendix E. At around midday, the thermal loads of the building reach a peak, which is when the TES system is being operated at full capacity. A thermal load profile of the Electrical Engineering building in Fig 6.4 confirms this.

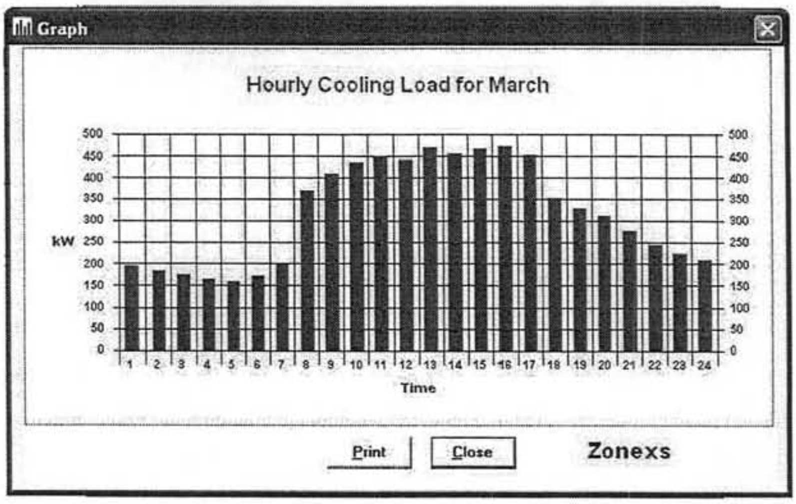


Fig 6.4: Thermal Profile for Building in Durban Area

The cooling load required to maintain a dry bulb temperature of 22.5 °C is shown above. The load peaks at midday and then gradually drops off until the outdoor temperature starts to drop in the evening.

6.2.2. Memorial Tower Building

Memorial Tower Building (MTB) is an independent chilled water system that operates on demand, as shown in Fig 6.5.

There are 2 dual circuit reciprocating York chillers, which supply chilled water to MTB and TB Davis. There are also 3 Evapco cooling towers.

The installed capacity of the above equipment is 360 kW. The energy index table for this feeder is given in Appendix E.

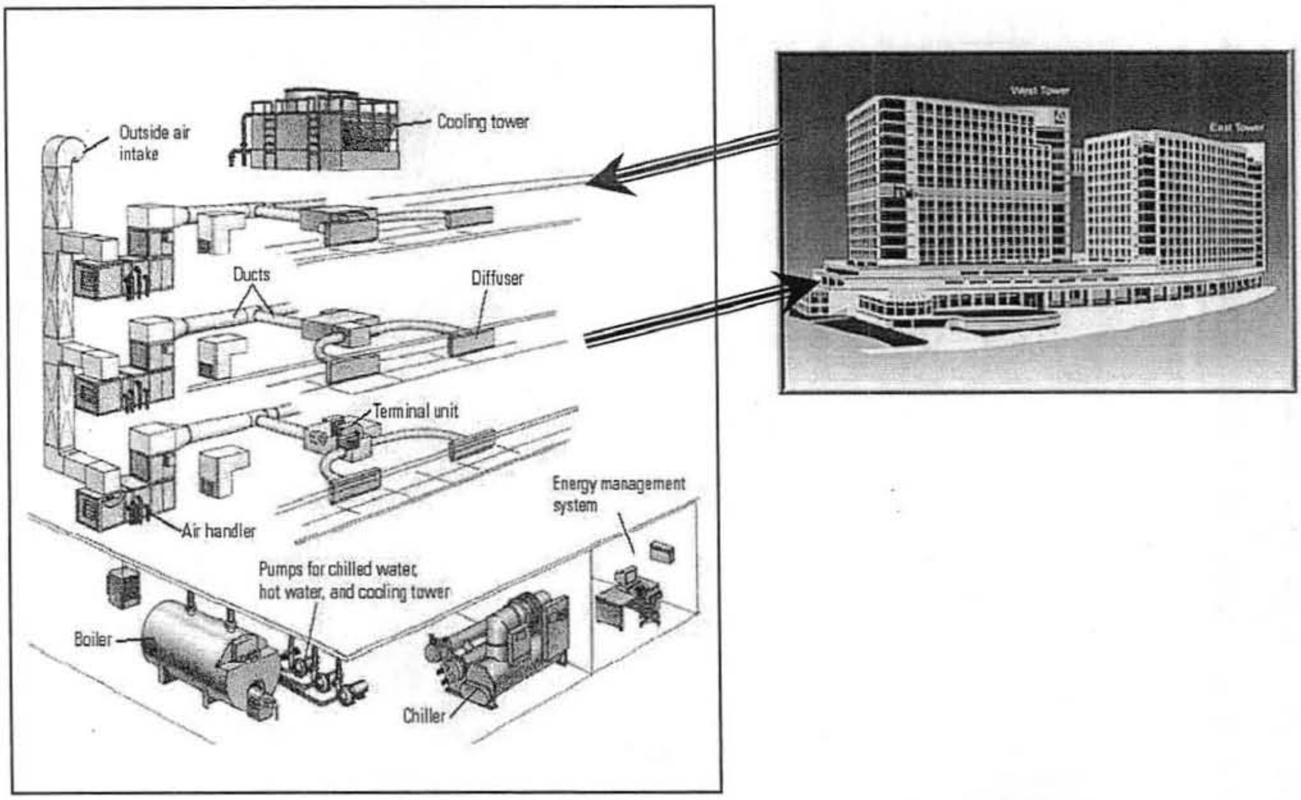


Fig 6.5: Memorial Tower Building Chilled Water System

The measured the monthly load profiles for summer and winter respectively are given below in Fig 6.6 and Fig 6.7:

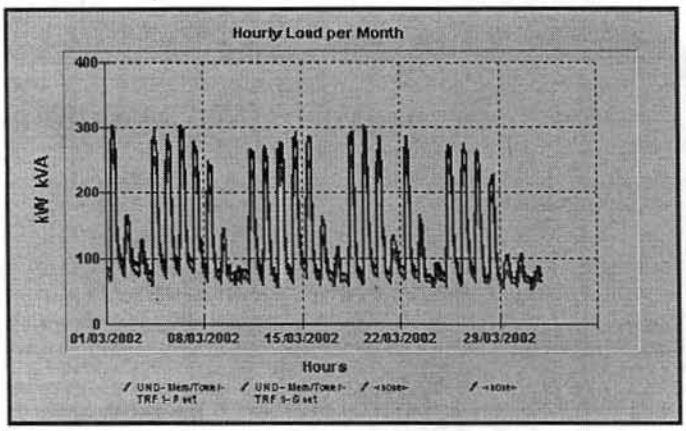


Fig 6.6: MTB Monthly Load Profile (Summer)

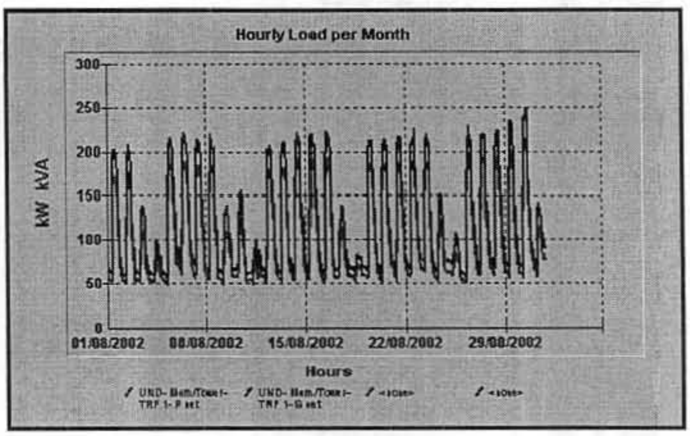


Fig 6.7: MTB Monthly Load Profile (Winter)

The summer demand is 300 kVA in February/March and 200 kVA during the colder winter days. This is to be expected considering that this feeder is dedicated to feeding the air-conditioning load only for MTB and TB Davis.

Recorded weekly load profiles during summer and winter periods are shown in Fig 6.8 and Fig 6.9:

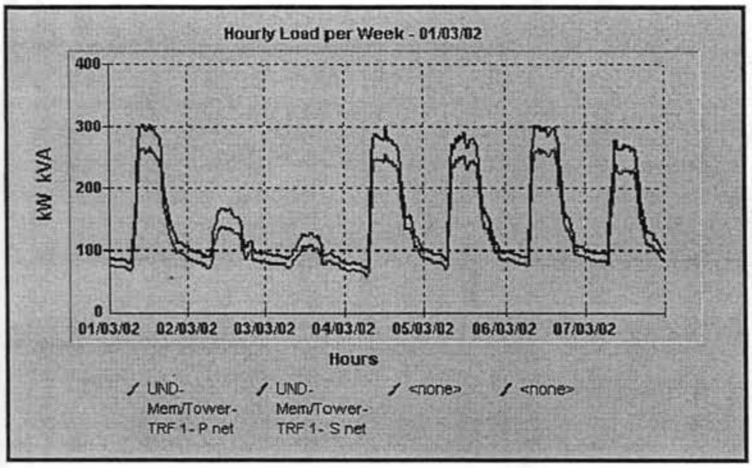


Fig 6.8: MTB Weekly Load Profile (Summer)

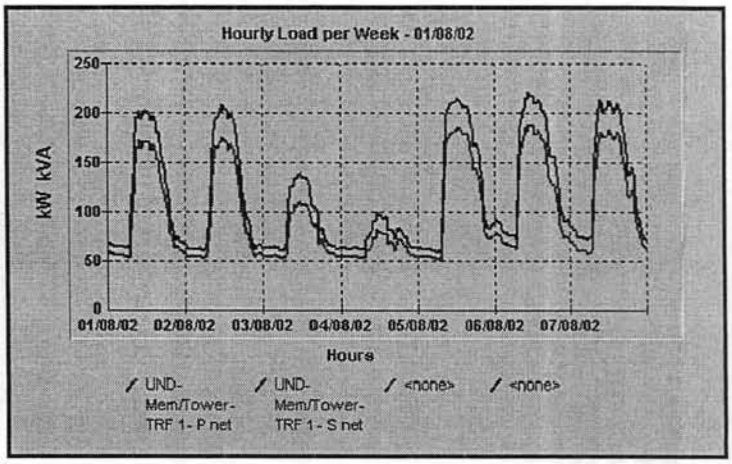


Fig 6.9: MTB Weekly Load Profile (Winter)

This system provides cooling as required by the occupant. As shown by the thermal profile in Fig 6.4, the peak load on the system coincides with the most expensive period of the tariff.

Examining the load duration curves reveal the following:

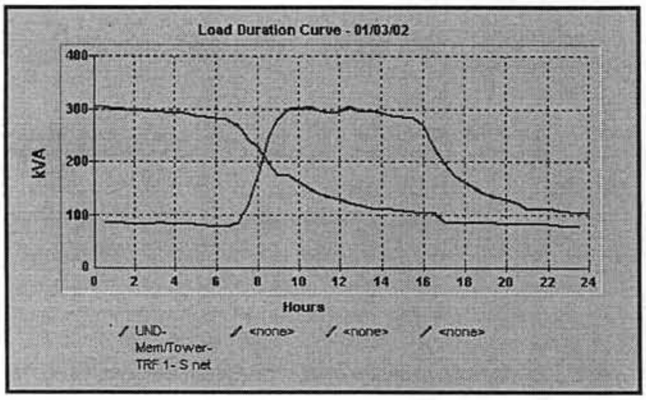


Fig 6.10: MTB Load Duration Curve (Summer)

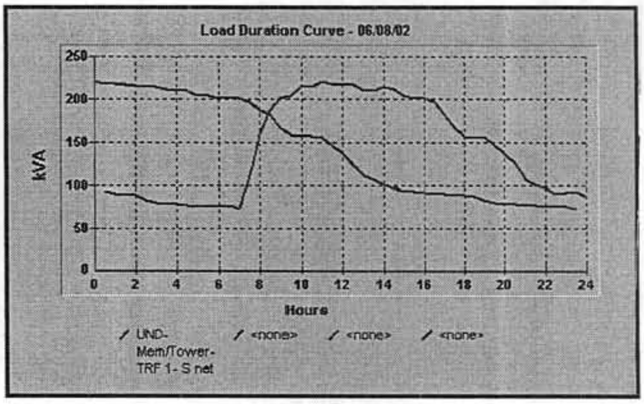


Fig 6.11: MTB Load Duration Curve (Winter)

The daily load curves (as shown in Figs 6.10 and 6.11) are very similar in **shape** to the thermal load profile (as shown in Fig 6.12) of the building. Energy savings can be made by examining the building envelope and by reducing the heat load profile in the building. Methods to accomplish this are beyond the scope of this study and hence are not discussed further.

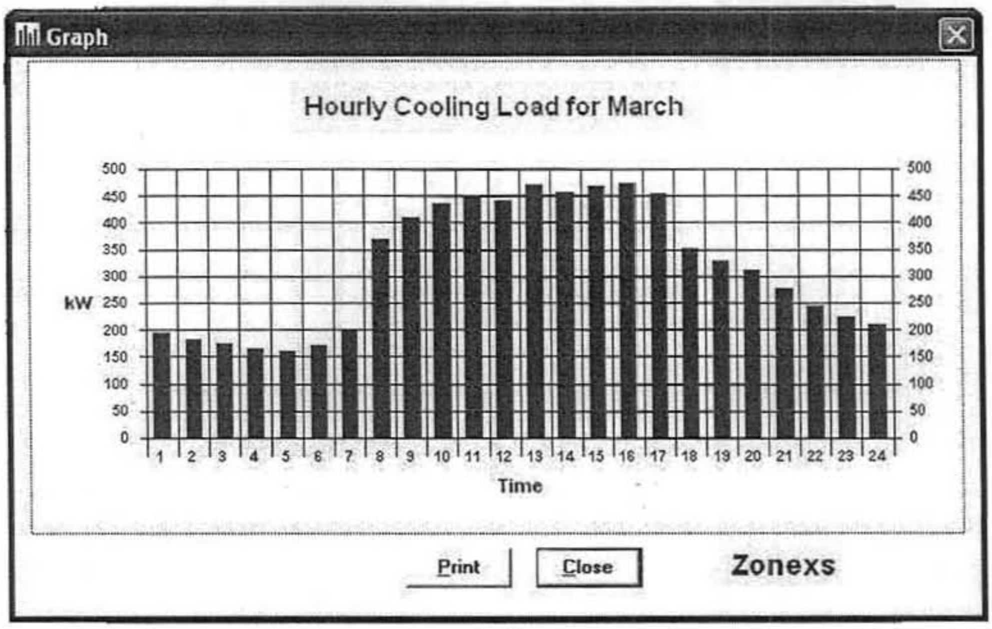


Fig 6.12: Thermal Profile for Load Control Purposes.

This system can possibly be used to do demand limiting. Further investigations need to be carried out to determine what the effect intermittent switching of subsystems will have on the overall effect of the system.

6.2.3. South Core Plant

The South Core Plant is also a Thermal Energy Storage (TES) system. There is a tank with a 2.3 million-litre capacity that is stored under the biology greenhouse. This system is used to supply air-conditioning to the George Campbell Building Complex. This is also known as the Biology feeder. The chiller has a cooling capacity of 704 $kW_{refrigeration}$. The installed capacity of the electrical equipment for this plant is 245 kW.

The current configuration of the system is to get a temperature difference of 5 °C between the inlet and outlet of the tank. There are two chillers connected in parallel at the moment, and the chilled water goes through two cycles to get a temperature difference of 10 °C.

The annual monthly demand fluctuates between 133 kVA in January and 81 kVA in June. This feeder has an average cost of 18.35 c/kWh which is well below the 19.99 c /kWh for main incomer. This low unit cost is compliant with a Thermal Storage System. The load factor is approximately 0.63 for the year, which is reasonably good.

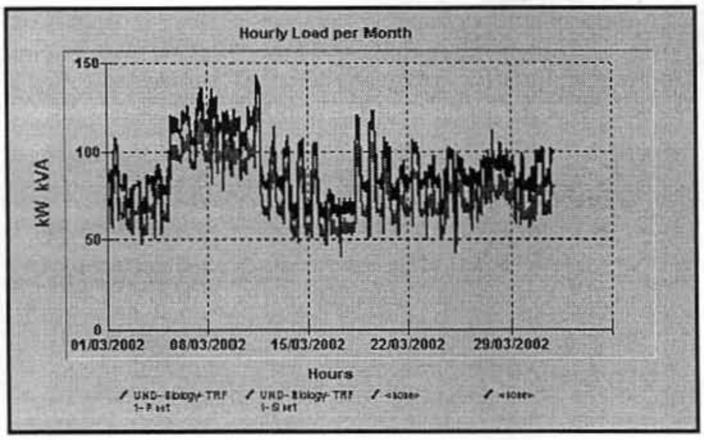


Fig 6.13: Biology 1 Summer Monthly Load Profile

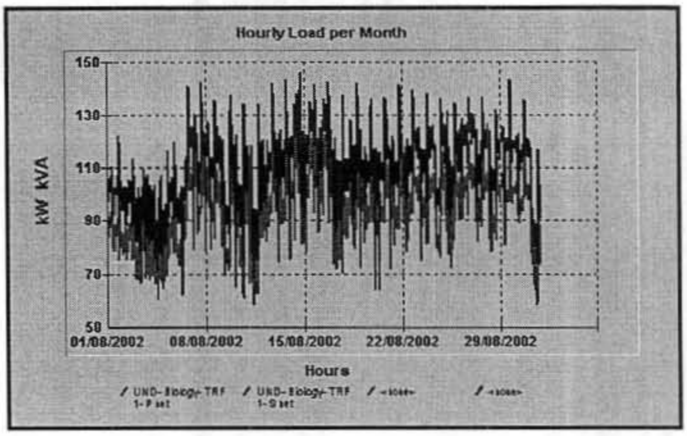


Fig 6.14: Biology 1 Winter Monthly Load Profile

Figs 6.13 and 6.14 indicate that the energy use is highly sporadic and does not have defined energy patterns. To get a better resolution of the graph, typical weekly profiles for summer and winter are shown below in Figs 6.15 and 6.16.

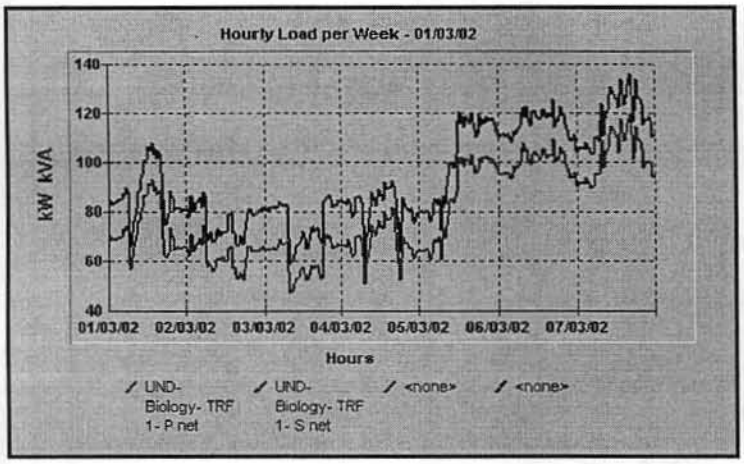


Fig 6.15: Biology Feeder1 Weekly Load Profile (Summer)

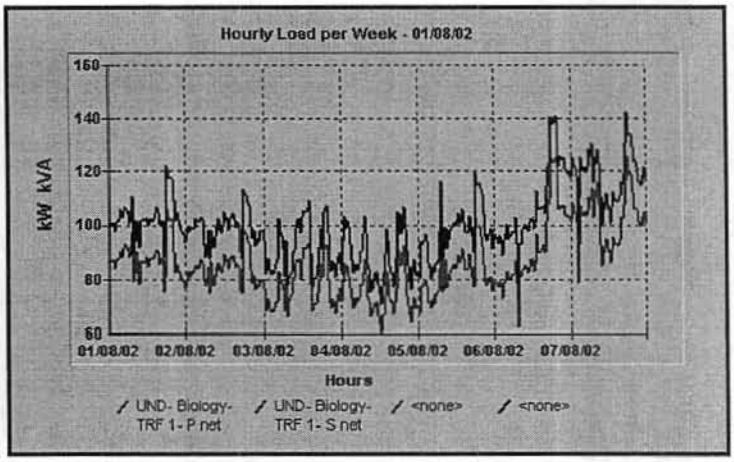


Fig 6.16: Biology Feeder 1 Weekly Load Profile (Winter)

The above weekly graphs also confirm the erratic nature of energy consumption for the feeder. The "typical" TES profile can be recognised on certain days, but on other days the bulk of the energy usage occurs during the peak periods. This needs further investigation to determine the cause of this.

There is also a small ice plant that supplies the plant nursery area in George Campbell. The power drawn by this plant is approximately 8 kW. This is a small plant compared to the other central plants and therefore will not be analysed.

6.2.4. Air Cooled Chiller Plants

There are dedicated air-cooled chiller plants at the Francis Stock Building and Mechanical Engineering Building. Air-cooled systems eliminate the need for a cooling tower and its associated water pumps, piping, and fans, reducing installation and maintenance costs. However, air-cooled chillers are substantially less energy-efficient than water-cooled models. As system tonnage rises, the merits of choosing a water-cooled system increase. This is a very similar system to the split unit system discussed above, except that it is on a larger scale. Chilled air is transferred to the point of use by ducts that run through the building.

The thermal energy provided by these systems, with the electrical rating is as follows:

- Mechanical Engineering 180 $kW_{refrigeration}$ 54 $kW_{electrical}$
- Francis Stock 158 $kW_{refrigeration}$ 52 $kW_{electrical}$

6.2.5. Unitary Equipment

Unitary Equipment is the window air conditioner unit that implements a complete air conditioner in a small space. There are a variety of sizes and types of this equipment that is scattered across the main campus. A summary of the equipment surveyed is given in Table 6.4.

As can be seen from the table above, the unitary equipment currently accounts for approximately 1.7 MW in installed air-conditioning capacity, on the Main Campus. Appendix E has a comprehensive list for each building. This is an uncontrolled load that would typically run during the most expensive part of the tariff. Possible methods to reduce or control this load will be discussed in the recommendations. This load also contributes to the baseload, as it was found that occupants tended to leave their air-conditioning units running when they left for the day.

BUILDING	BLDG NO.	Window	Console	SPLIT TYPE UNITS					Package	TOTAL NO.
				Midwall	Console	Cassette	Underceiling	Ducted		
ANSELL MAY	049	1	0	0	0	0	0	0	0	1
CHARLES JAMES	048	1	0	0	0	0	0	0	0	1
CHARLES SMITH (ISLAND OFFICES)	047	4	0	0	0	0	0	0	0	4
DENIS SHEPSTONE	010	53	6	11	0	1	6	10	4	91
E.G. MALHERBE	391	0	0	1	0	0	0	0	0	1
FRANCIS STOCK	054	3	31	17	2	0	4	1	0	58
FRANCIS STOCK PREFAB	055	2	1	3	0	0	0	0	0	6
G.C. SCULLY HALL	028	1	0	0	0	0	1	1	0	3
G.C. SCULLY HALL (MABEL PALMER BEER CLUB)	031	2	0	0	0	0	0	0	0	2
JUBILEE CENTRE	026	0	0	0	0	0	1	0	0	1
J.V. SMIT RESIDENCE	650a	0	0	2	0	0	0	0	0	2
MARY WESTON TRUST FLAT 8	422a	0	0	2	0	0	1	0	0	3
MEMORIAL TOWER BUILDING	020	41	59	9	11	0	10	26	2	158
TOWNLEY WILLIAMS	021	1	0	0	0	0	0	0	0	1
TOTALS FOR BUILDINGS		109	97	45	13	1	23	38	6	332
APPLIED CHEMISTRY (FORESTRY)	139	21	3	4	1	0	12	1	0	42
CHEMICAL ENGINEERING	086	8	15	2	0	0	3	6	0	34
CHEMISTRY	059	43	7	3	0	0	6	7	0	66
DURBAN CENTENARY	051	22	31	5	3	0	6	8	0	75
ELECTRICAL ENGINEERING	001	25	0	2	3	0	9	1	0	40
HUTMENTS	069\073 &	12	2	0	1	0	1	3	0	19
SPEECH & DRAMA STUDIOS	075\079	0	0	0	0	0	0	9	1	10
TOTALS FOR BUILDINGS		131	58	16	8	0	37	35	1	286
ADMIN ANNEXE	056	4	0	0	0	0	0	1	0	5
STUDENT COUNSELLING	057\058	1	11	2	0	0	0	0	0	14
CLINIC	396	7	0	0	0	0	0	1	0	8
DESMOND CLARENCE	061	29	30	8	0	2	16	9	0	94
GEORGE CAMPBELL	062	19	0	9	0	1	0	1	0	30
HOWARD COLLEGE	018	4	0	3	0	0	1	0	0	8
MECHANICAL ENGINEERING	052	4	2	7	4	0	1	0	0	18
CAMPBELL HOUSE - 267 KING GEORGE V AVE	039	0	1	3	1	0	0	0	0	5
RICK TURNER STUDENTS UNION	060	22	1	10	6	0	1	0	0	40
SCHOOL OF MUSIC - BLOCK A,B & C	015\017	4	2	6	4	0	0	4	0	20
T.B. DAVIS	068	5	0	0	0	0	1	0	0	6
TOTALS FOR BUILDINGS		99	47	48	15	3	20	16	0	248
TYPE TOTALS		339	202	109	36	4	80	89	7	
TOTAL NUMBER OF UNITS		866								

TOTAL COOLING CAPACITY (Btu's)	17,363,000	Btu
TOTAL COOLING CAPACITY (KWr)	5,089	KWr
TOTAL ELECTRICAL LOAD (KWe)	1,696	KWe

Table 6.4: Unitary Air-conditioning Equipment Register

As many as practically possible of the above units need to be phased out over a period of time, in favour of a central system. Where the use of unitary equipment is the only feasible solution, equipment with a Seasonal Energy Efficiency Rating (SEER) of 10 and above should be used. Energy Star accredited appliances have SEERs of 12 and above.

Chapter 7

Lighting Systems

7.1. Introduction

This chapter examines lighting systems. Of all the energy conservation interventions, lighting retrofits are one of the easiest types of interventions to comprehend. Prior to this study, there was an energy management committee in place that was operating under the auspices of the external facility managers. Although this committee was mandated to exercise energy management, there was no real commitment from the university management to this cause. This committee had no budget or accountability, which hampered any real progress towards judicious use of energy. There had been numerous presentation made to management and several energy saving scenarios presented to management. None of these suggestions were followed up on. One of the main reasons for this was sceptism from management regarding the projected savings that were presented to them. In fact, when this case study (which was being paid for by external funders, with no obligation to the University) was presented to senior management, one of the comments received was that "we don't need a fur coat". The implication of this statement is that energy management interventions are seen to be over and above the business as usual, and that it does not make economic sense.

This case study is used to demonstrate the energy management and energy conservation does indeed make economic sense, in addition to all the other associated benefits. The accuracy of the cost saving projection models will also be verified during this exercise. The results of a lighting case study that was implemented on the Main Campus are reviewed. Important lighting theory is included in Appendix F.

7.2. Lighting Case Study EG Malherbe Lighting Retrofit

7.2.1. Project Background

BONESA recently funded a complete lighting retrofit to totally energy efficient light fittings in the EG Malherbe Library at the University of Natal, Durban. BONESA- which means "to lighten up" in Setswana- a joint venture company funded by Eskom and the Global Environment Facility (GEF) is responsible for the Efficient Lighting Initiative (ELI) in South Africa. ELI is aimed at reducing electricity demand, increasing efficiency and reducing emissions through the promotion of efficient lighting throughout South Africa.

BONESA's brief from their funders was to transform market behaviour and encourage industry and other users into choosing energy efficient light fittings as their first choice in any new or existing lighting installation. A big obstacle that BONESA faced was, that due to current low energy prices, the payback period on some lighting projects was longer than the normal industry standard of 18 to 36 months. This was especially true of retrofitting existing projects. Due to the above, any mention of efficient lighting was greeted with some amount of sceptism. Therefore BONESA had decided to implement showcase projects in different key sectors to demonstrate that energy efficient lighting was indeed practical and could indeed be implemented whilst being financial sense as well. The EG Malherbe Library was chosen by BONESA as the showcase project in the institutional sector, as part of the Johannesburg World Summit on Sustainable Development.

Every year, the University of Natal spends over R4 million toward electricity usage on the Durban campus alone. The EG Malherbe Library contributes a substantially toward this cost. The total electricity cost for EG Malherbe in 2001 was R473 337, of which R 353 306.58 was spent to energise the lighting load. The pre-installation lighting system was 14 years old and close to the end of it life. An additional problem was that the pre-installation lighting system was redundant - it was a specialised fitting manufactured by Zintubel – Zintubel had closed down a few years earlier. Therefore the timing of this project was excellent.

An energy audit had to be conducted first to determine the viability of retrofitting the pre-installation lighting system with a more efficient lighting system. The project is discussed in greater detail below.

7.2.2. Site identification and description

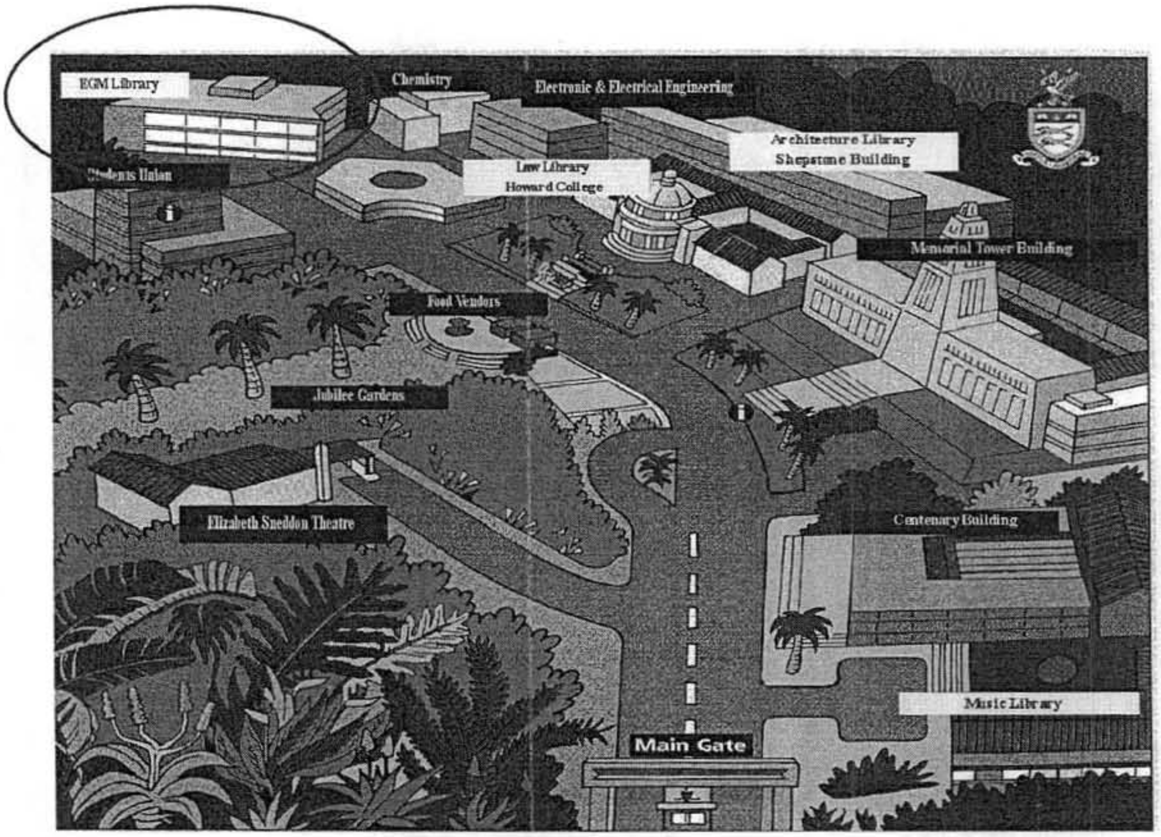


Fig 7.1: Location of EG Malherbe Library

The building under study is the EG Malherbe Library at the University of Natal, Durban. It is located in the centre of the Durban campus (Fig 7.1) and serves the needs of staff and students of the Faculties of Community and Development Disciplines, Engineering, Human Sciences, Management Studies and Science. The E G Malherbe Library was opened in May 1988. The building has four levels above ground and one level below ground level. The total floor area that was retrofitted is 8164.22 m^2.

The entire gross external wall consists of heat reflecting windows. The heat reflecting windows consists of a tinted solar film on the external façade of the building, sandwiched between two layers of glass.

The building occupancy levels are variable but are normally close to capacity levels prior to and during examination periods.

The hours of occupation are as given in Table 7.1:

Weekdays:	8:00 to 23:00
Saturdays	8:30 to 17:00
Sundays and Pub Holidays:	Closed except during examinations
Between Semesters:	08:00 to 17:00
Examination operation hours are (one month prior to exams and during exams) Mon to Fri:	8:00 to 02:00 the next morning.
Examination operation hours - Saturdays	8:00 to 17:00
Examination operation hours - Sundays	9:00 to 17:00

Table 7.1: Operating Hours of EG Malherbe Library

The pre-installation used approximately 2500 fittings of which the bulk was 2x36 w fluorescent fixtures with magnetic ballasts in the common areas used by the students. The audit data in shown in Table 7.2.The light levels in the previous inefficient installation using 2x36 W fittings were on average between 300 and 400 lux in the common areas.

Luminaire Type	Number of Luminaires
2 x 36 W Open Channel	2051
2 x 60 W down lighter	263
1 x 58 W Tube Light	60
4 x 18 W Recessed Fittings	220
4 x 36 W Recessed Fittings	19
2 x 56 W Surface Mounts	83
2 x 36 W Surface Mounts	32
1 x 36 W Tube Light	28
1 x 36 W Open Channel	20

Table 7.2: Pre-implementation Luminaire Audit Data

The circuits feeding the lighting system were measured. The real power, apparent power and power factor was recorded. An energy model was then developed, as summarised in Table 7.3.

7.2.3. Audit Data and Energy Savings Model

Audit Data Report - University of Natal									
EG Malherbe Library									
	Type 1	Type 2	Type 3	type 4	Type 5	Type 6	Type 7	Type 8	Type 9
Area	2 x 36w Open Channel Luminaire	2 x 60 w Incandescent D/L	1 x 58 w Tube Light	4 x 18 w Recess Luminaire	4 x 36 w Recess Luminaire	2 x 56 Surface Mounted Luminaire	2 x36 w Surface Mounted Luminaire	1 x 36 w Tube Light	1 x 36 w Open Channel Luminaire
Lower Ground Floor		72		165		73	32		
Stairs								28	
Centre Core			60						
Ground Floor	299	69		7	19				58
1st Floor	364	44							71
2nd Floor	341	44							71
3rd Floor	347	50							71
4th Floor	342	43							72
Total	2051	263	60	220	19	83	32	28	20
Luminaire Wattage	92	120	71	96	200	150	105	50	50
Luminaire VA	124	0	91	107	247	178.6	135	66	67.5676
Luminaire Power Factor	0.74	0	0.78	0.9	0.81	0.84	0.78	0.76	0.74
Total System Wattage	188692	31560	4260	21120	3800	12450	3360	1400	1000
Total System VA	254989	0	5461.5	23467	4691.4	14821	4307.6923	1842	1351.35
Total Active Energy Consumption - All LUMINAIRES							**268 kW**		
Total Apparent Power Consumption - All LUMINAIRES							**311 kVA**		

l x 36 w Monophosphor Lamp		
Lamp Life	7000 hours	*Based on suppliers specification*
Lamp Replacement Cost per unit	8.50 Rand	*Lamp Cost = 5.50; Labour Cost = 3.00*
Average working hrs per annum	4778.00 Hours	
Lamp Replacement Cost per annum	5.80 Rand	
60 w Incandescent Lamp		
Lamp Life	1000 hours	*Based on suppliers specification*
Lamp Replacement Cost per unit	4.5 Rand	*Lamp Cost = 1.50; Labour Cost = 3.00*
Average working hrs per annum	4778.00 Hours	
Lamp Replacement Cost per annum	21.501 Rand	
l x 58 w Monophosphor Lamp		
Lamp Life	6000 hours	*Based on suppliers specification*
Lamp Replacement Cost per unit	12.50 Rand	*Lamp Cost = 9.50; Labour Cost = 3.00*
Average working hrs per annum	4778.00 Hours	
Lamp Replacement Cost per annum	9.95 Rand	
l x 18 w Monophosphor Lamp		
Lamp Life	6000 hours	*Based on suppliers specification*
Lamp Replacement Cost per unit	8.80 Rand	*Lamp Cost = 5.80; Labour Cost = 3.00*
Average working hrs per annum	4778.00 Hours	
Lamp Replacement Cost per annum	7.01 Rand	

Table 7.3: Audit Report

The operating hours for the library are established and verified. The change in demand and energy now needs to be determined. A notch test was performed to determine what the pre-implementation demand was.

A notch test is a test in which the current is logged and the system under study is switch on and off. The effect of the studied system on the total current will then be seen on the logged electricity consumption profile.

A typical notch test is performed in the following manner:

1. A logger with a current transducer is used to measure all three phases of the total current.
2. The studied system, in this case the lights, is switched off and data is logged for three minutes.
3. The studied system is then switched back on and data is logged for three minutes.
4. Repeat steps 2 and 3, at different intervals, depending times.

The results of the notch test are shown in Appendix G.

From the notch test, it can be seen that the internal lighting contributes approximately 170-kVA demand to the energy consumption of the facility. The active energy demand is approximately 158 kW.

Although the library has central light switching, it was discovered that this central switch did not include the lighting in the administration section of the lower ground floor and for some administration offices on the ground floor. The purpose of the central switch was merely to switch the lights in the common areas, and the administration areas were individually switched to allow staff to work in these areas, without switching on the all of the lighting in the library, when the library was not opened to the general university population. It was found by examining the daily load profile, in one-minute increments, that the total pre-implementation consumption (including the above-mentioned administration areas) the total internal lighting contributed 210 kW of active energy and contributed 221 kVA to the demand component.

There were 263 x (2 x 60 W) incandescent lamps that were not operational at the time of the audit. Theses lamps were not installed and never replaced due to the high theft rate of these lamps. These were be replaced with 11 W PL lamps to counter this problem. Therefore this component needs to be added to the baseline, as the lighting system will be restored in the retrofit. This will add 31.5 kW to the active energy component and 31.5 kVA to the demand component. This concept is illustrated in Fig 7.2 below.

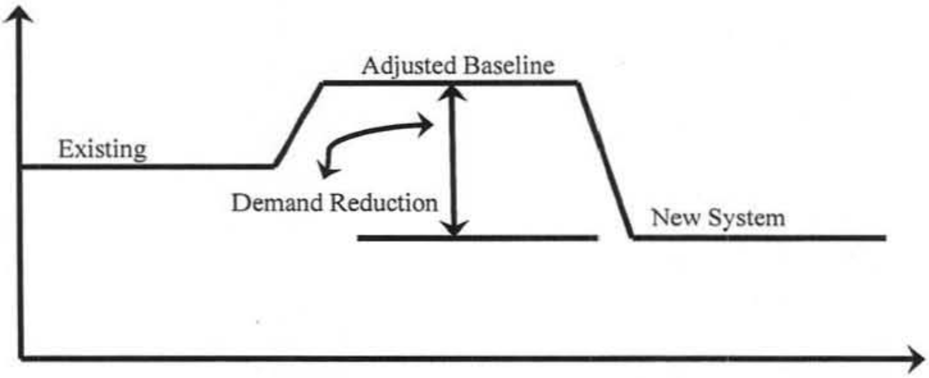


Fig 7.2: Baseline Adjustment

Therefore the pre-implementation demand is 252.5 kVA and the real power component is 241.5 kW. The **projected savings** are summarised in Table 7.4 below. The complete energy analysis is included in Appendix G.

Overall Project Summary	
Total Project Costs Including Materials & Labour to install	R 806,727.00
Total Ex. Energy Costs per Annum	R 353,306.58
Total New Electricity Costs per Annum	R 134,052.23
Total Savings per Annum (Electricity Only)	R 219,254.35
Payback Period no Inflation	3.68
Payback Period with Inflation	3.29

Table 7.4: Overall Project Summary

The verified post implementation saving will have to be in the region of R 219 254.35 to prove that the methodology followed and the model used can be reliably used to determine business cases for energy conservation projects.

7.2.4. The Design Process

It was decided to retrofit the existing luminaires (Table 7.5) with the luminaire types in Table 7.6:

Luminaire Type	Number of Lamps
2 x 36 W Open Channel	2051
2 x 60 W down lighter	263
1 x 58 W Tube Light	60
4 x 18 W Recessed Fittings	220
4 x 36 W Recessed Fittings	19
2 x 56 W Surface Mounts	83
2 x 36 W Surface Mounts	32
1 x 36 W Tube Light	28
1 x 36 W Open Channel	20

Table 7.5: Pre-Implementation Audit Data

Luminaire Type	Number of Lamps
1 x 36 W Surface Mounted Luminaire with Trifocal Reflector	2051
2 x 11 W PL Lamp	248
Retrofit of lamp only for 1 x 58 W Tube Light	60
3 x 18 W LBR	224
2 x 36 W LBR	19
1 x 36 W Open Channel	83
1 x 36 W Open Channel	32
Retrofit of lamp only for 1 x 36 W Tube Light	25
2 x 18 W	20

Table 7.6: Post-Implementation Audit Data

With the new installation, the 2 x 36 W fittings were retrofitted with 1 x 36 W fittings. The pre-installation luminaire operated with a mono-phosphor lamp and magnetic ballast. The post-implementation luminaire consisted of an electronic ballast with a tri-phosphor lamp. Tri-phosphor lamps give better colour rendition and have an improved lamp life over the mono-phosphorus lamps. Their lumen output is also superior to mono-phosphor lamps. A trifocal reflector was included in the luminaire to reflect all the lights lost in the coffers in the ceiling. The light levels were found to be between 600 and 800 lux, in comparison to the pre-implementation levels of 300 to 400 lux.

The recommended post-implementation lighting system was first tested using a simulation package.

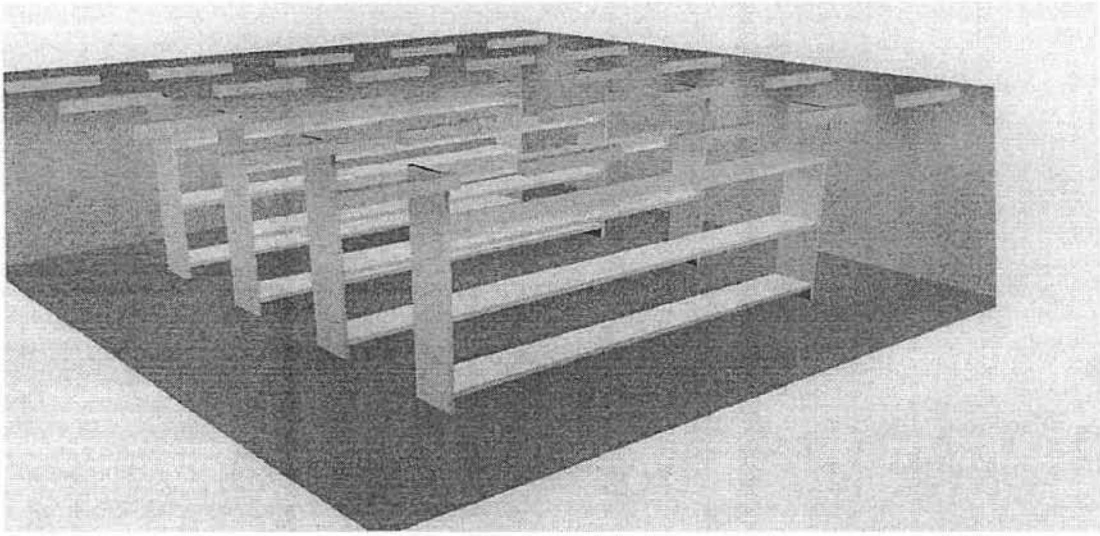
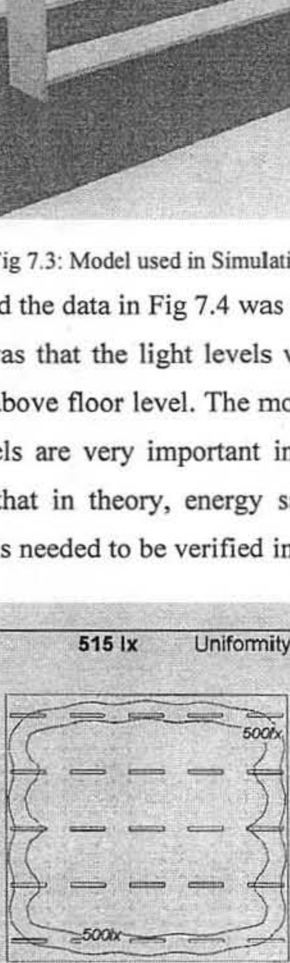


Fig 7.3: Model used in Simulation

The model in Fig 7.3 was used and the data in Fig 7.4 was obtained. The impressive feature in the simulated proposed design was that the light levels were uniform 600 lux between the floor level and about 2.5 meters above floor level. The mounting height was approximately 3 metres. These uniform light levels are very important in a task lighting application like a library. The simulation proved that in theory, energy savings could be achieved without compromising on light levels. This needed to be verified in practice.

Results

Average Illuminance **515 lx** Uniformity (Emin/Eav) 0.58



E (lx)	9.71m	9.12m	8.53m	7.94m	7.35m	6.76m	6.18m	5.59m	5.00m	
5.00m	399	476	501	518	548	553	541	553	568	5.00m
4.41m	426	510	539	558	589	594	584	596	610	5.59m
3.82m	441	527	560	580	610	615	607	619	631	6.18m
3.24m	412	493	519	537	568	573	562	574	588	6.76m
2.65m	407	486	512	529	560	564	553	565	579	7.35m
2.06m	435	520	552	572	601	606	598	609	622	7.94m
1.47m	419	500	530	548	577	582	572	584	597	8.53m
0.88m	352	420	439	452	479	482	470	481	494	9.12m
0.29m	297	353	367	378	400	402	392	401	413	9.71m
	0.29m	0.88m	1.47m	2.06m	2.65m	3.24m	3.82m	4.41m	5.00m	

Improper use of ELTC will result in inefficient lighting solutions. Data and results my change following technological developments.
Please contact your ETAP sales team for the most complete advice.

Fig 7.4: Simulated Average Illuminance Levels

7.2.5. Post-Implementation Results

As the pictures in Figs 7.5 and 7.6 illustrate the light levels between the bookshelves had improved quite substantially. This was especially important for the books that are normally housed in the lower shelves near the floor.

Fig 7.5: Lighting Levels Before Retrofit

Fig 7.6: Lighting Levels After Retrofit

The use of a trifocal reflector also added approximately 200 lux of useful light in the working plane. As the pictures below illustrate, in the pre-installation lighting system approximately 30% of the light was being lost in the coffers. Using the trifocal reflector helped to reflect this light back onto the working plane. The reflector is made from highly polished aluminium.

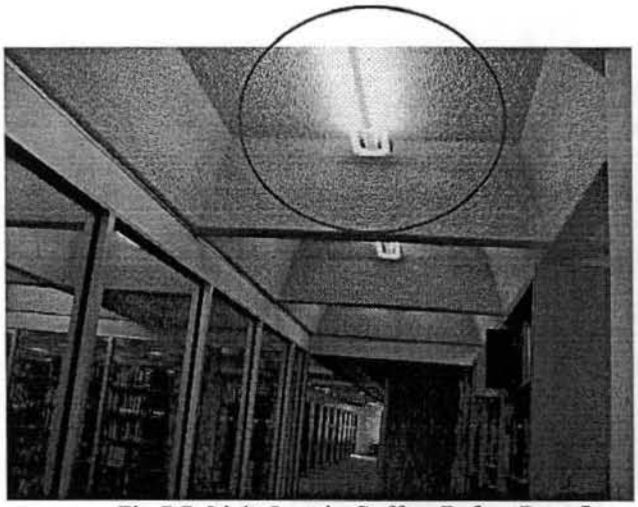


Fig 7.7: Light Lost in Coffers Before Retrofit

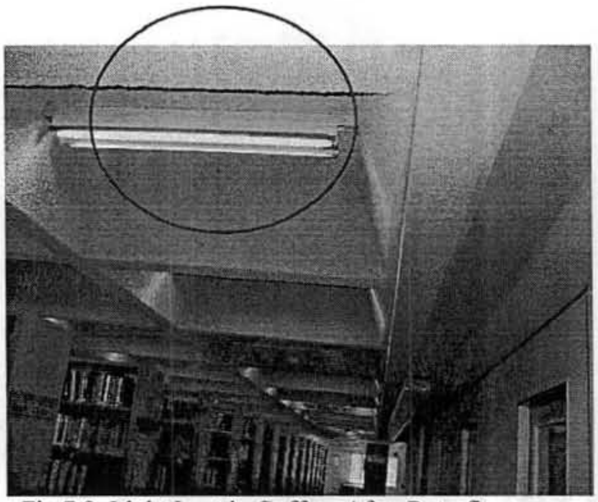


Fig 7.8: Light Lost in Coffers After Retrofit

Notice in Fig 7.7 above, the amount of light in the coffers itself (circled in red). The light is not needed at this point but is needed on the working plane. Fig 7.8 shows how the coffer is much darker in the post-implementation lighting system. This previously "lost" light is now being reflected back onto the working plane.

There have been some industries that have expressed reservation about using electronic ballasts. Due to their nature of operation there has been claims that they introduce harmonics and adversely affect the quality of supply. Whilst it is true that with increased switching the harmonic levels should increase, it is also true that the reduction in load should negate this. With the EG Malherbe installation, it was found that the harmonics had actually decreased in the building after the installation. This is illustrated in the Fig 7.9 below.

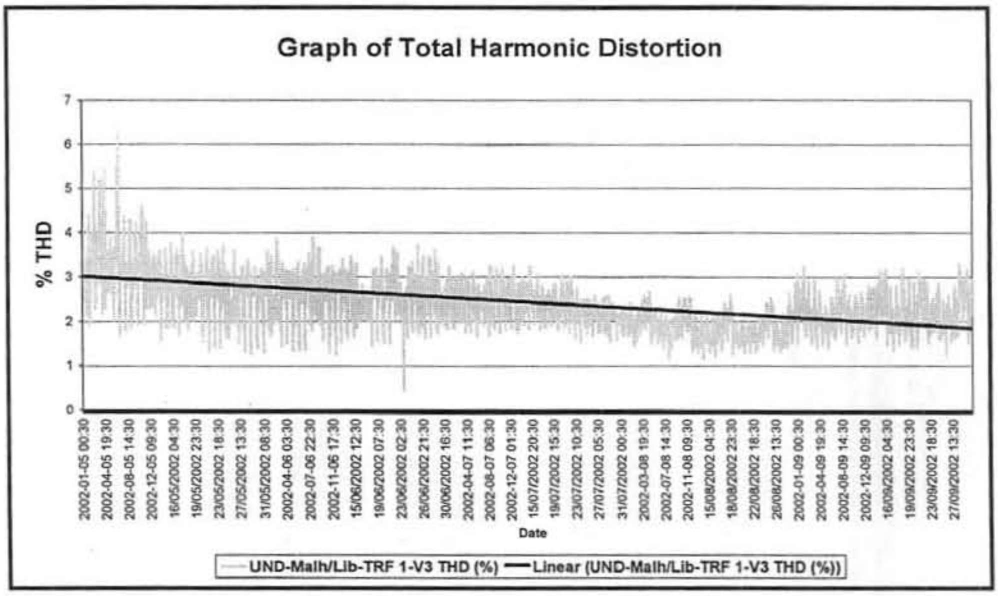


Fig 7.9: Harmonic Distortion Reduction

Whilst power quality is important, the prime reason for the implementation of this project was the demonstration that energy savings could be made. After the implementation was complete the energy consumption was measured (as it was prior to the installation). To determine energy savings all that was needed was to determine the active energy saved as well as the reduction in demand, and compute the savings using the tariff. The following equations were used:

$$kWh_{saved} = (kW_{old\ luminaire} - kW_{new\ luminaire}) \times Quantity \times Operating\ Hours \quad (7.1)$$

Where:

kWh_{saved}	=	Active energy not being used due to reduction in load
$kW_{old\ luminaire}$	=	The installed electrical capacity of the luminaries used in the pre-implementation lighting system.
$kW_{new\ luminaire}$	=	The installed electrical capacity of the luminaries used in the post-implementation lighting system.

Operating Hours = Number of operating hours that the lighting system is switched on for.

$$kW_{savings} = kW_{old\ luminaire} - kW_{new\ luminaire} \quad (7.2)$$

Where

$kW_{savings}$ = Maximum demand savings realized on this project.

$kW_{old\ luminaire}$ = The installed electrical capacity of the luminaries used in the pre-implementation lighting system.

$kW_{new\ luminaire}$ = The installed electrical capacity of the luminaries used in the post-implementation lighting system.

The summary of the **actual energy costs savings** is given below. The complete energy savings report is included in Appendix G.

Overall Project Summary	
Total Peak kWh Saved Up Until May 2003	97410.00
Total Standard kWh Saved Up Until May 2003	306170.00
Total Off Peak KWh Saved Up Until May 2003	150705.00
Reduction in Demand per month	210.00
Total kWh Saved	554285.00
Total Cost Saving Ex VAT Up Until May 2003	R 123,793.82
Previous Demand in kVA	311.00
New Demand in kVA	101.00
Previous kW	268.00
New kW	98.00
Reduction in kW	170.00
Total Electricity Cost Saving Extrapolated for a Year	R 212,217.98

Table 7.7: Summary of Cost and Energy Savings

The projected cost saving in the initial audit saving was R 219 254.35 and the actual savings based on usage figures was calculated to be R 212 217.98. This indicates that the savings projection model is accurate to within a 4% error margin. This indicates that this model is reliable for determining future energy conservation business cases.

The installation commenced on the 15th July 2002. By examining the electrical load profile, a visual confirmation of the reduction in energy demand can be seen. The energy profile for 2001(red curve in Fig 7.10) was graphed on the same axis as the energy profile for the year 2002 (blue curve in Fig 7.10).

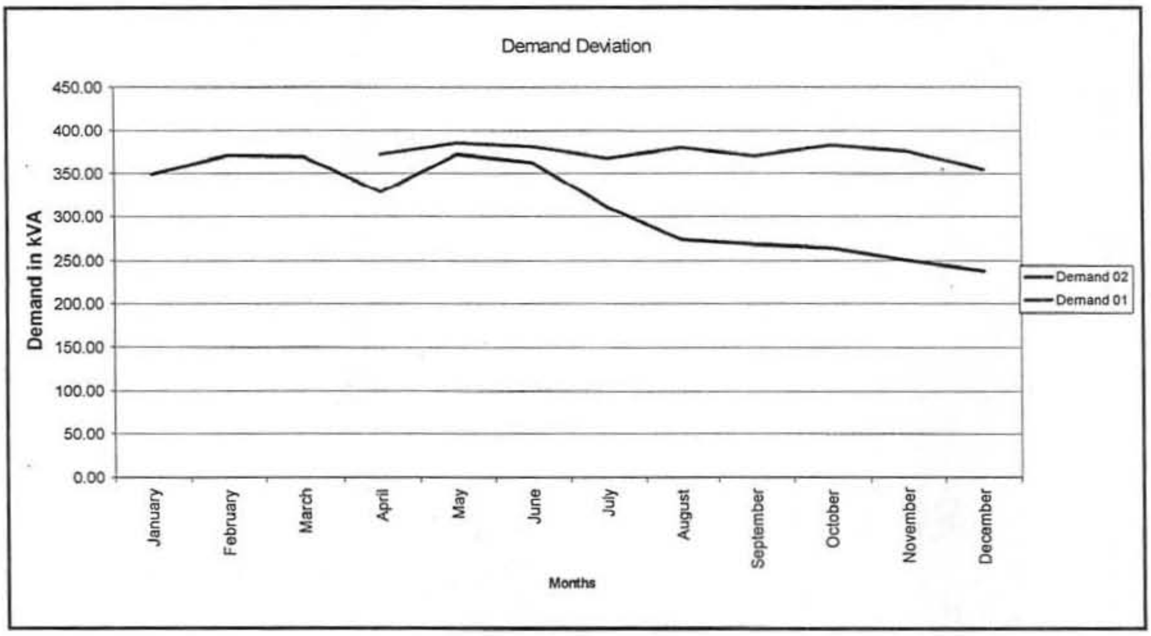


Fig 7.10: Demand Trend for 2001 and 2002

This reduction on energy usage also has environmental benefits, through reduced emissions due to power not being generated. The emission savings are given in Table 7.8:

Overall Emission Savings up until May 03			
Carbon Dioxide	892 kg/MWh	494422.22	kg
Nitrous Oxide	6 kg/MWh	3325.71	kg
Sulphide Oxide	7.2 kg/MWh	3990.85	kg
Particulate Matters	0.7 kg/MWh	388.00	kg
Water	1.23 Litre/kWh	681770.55	litres

Table 7.8: Emission Reductions

7.3. Remarks

The total cost to convert the lighting in the EG Malherbe library to totally efficient lighting cost just over R 800 000, including materials and labour. Whilst this is a large capital outlay, the savings made through reduced electricity costs are a staggering R 212 000 a year and the energy savings that have been projected are approximately 950 000 kWh which translates into approx 848 tons less carbon dioxide being released into the atmosphere. Note that these are savings only from reducing the lighting load in this building. A key to realizing such impressive savings was the fact that the library has long operating hours. The library also has a 24-hour air-conditioning requirement and the reduced heat load due to the energy efficient light fittings will also contribute to a saving in air-conditioning energy costs.

The Main Campus has an installed capacity of 1 647 kW of internal lighting. The bulk of these are 2 lamp 58W fluorescent fittings. These fittings have magnetic ballasts and operate with monophospor lamps. There is huge potential for savings by simply retrofitting these fittings with modern more efficient fittings, as in the case of the EG Malherbe Library. Current practices, at the University, dictate that the cheapest possible luminaire be installed for either new installations or replacing existing failed lamps/luminaires. As Fig 7.11 below indicates, the initial costs account for the lowest portion of the life-cycle costs.

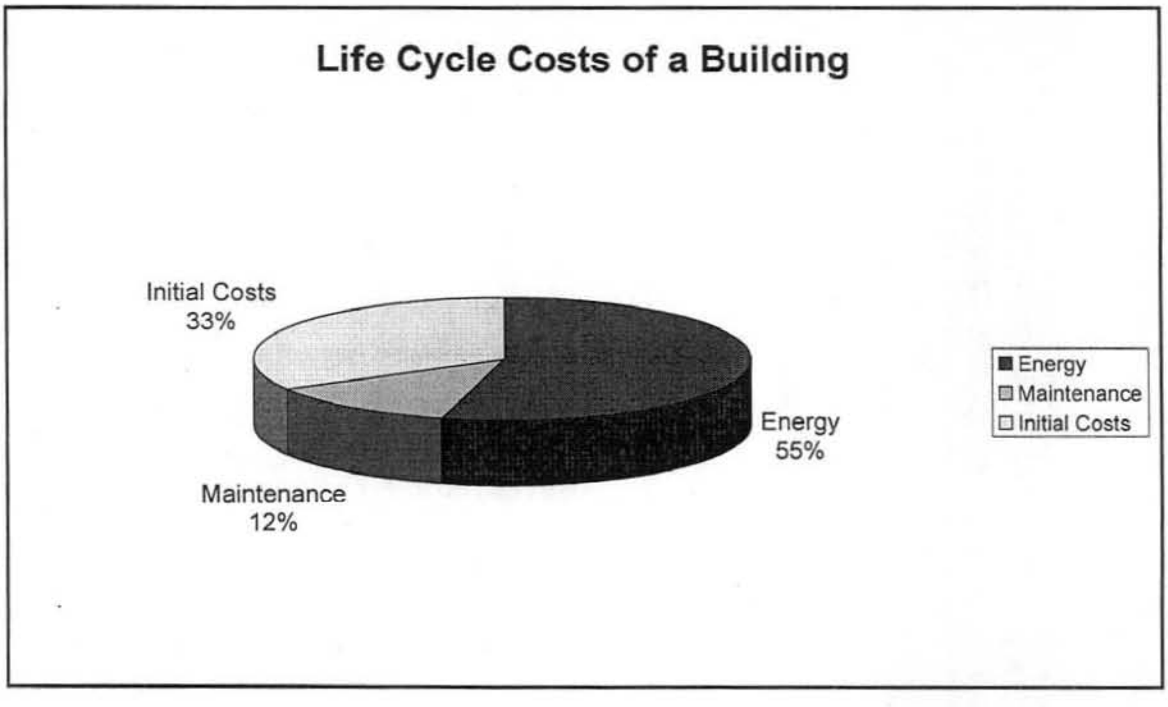


Fig 7.11: Life Cycle Costs of a Building (Source: Association of Energy Engineers, USA)

By installing energy efficient fittings the life-cycle cost for the lighting system will be substantially reduced. An added benefit is reduced maintenance costs through longer lamp/luminaire life.

Whilst it is understandable that a large motivator to keep first costs down is budget constraints, there are other funding avenues that are available, that are not presently being tapped. Such a source is the Eskom DSM project funds.

For new projects an applications could be put into Eskom DSM to get them to fund the cost differential in between the normally specified fittings and a more efficient fitting. A maintenance policy needs to be enforced where only approved energy efficient fittings are purchased and installed.

The lighting load also has a huge impact on the thermal load of a building. By reducing the lighting load, the thermal load will be reduced and so reduce the load placed on the air-conditioning system resulting in added savings [64].

A concerted effort needs to be made by the University management to realise the huge potential savings that can be made from implementing energy efficient lighting in all areas of the University.

Chapter 8: Recommendations and Conclusion

8.1. Introduction

The main objective of this thesis is to establish energy conservation opportunities for electricity cost savings to be made at the Howard College campus of the University of KwaZulu-Natal. These opportunities were to be identified from the results of an energy audit conducted on this campus. The specific objectives of the study are given in Table 8.1.

Specific Objectives of the Study		Objective Achieved and Where
1	To conduct an energy audit to identify major energy users on the campus	YES – Chapter 5 & Appendix C
2	To establish a database of historical energy consumption data for each building in the Durban campus.	YES – Chapter 5 & Appendix D
3	To further investigate the larger users of energy and quantify their energy consumption, and identify trends, where possible.	YES – Chapter 6
4	To make recommendations where possible, for savings to be made	YES – Chapter 7 & Chapter 8
5	To implement a case study demonstrating that energy management is a viable option.	YES – Chapter 7

Table 8.1: Specific objectives of the study

As can be seen from the above table, all of the objectives were met. A summary of the results will be given before further recommendations are made. The thesis will also be concluded in this chapter.

The main reason for establishing the above objectives was to create a base from which the energy management program could be established. At the beginning of this study, there was very little information on the energy usage patterns of the systems that were on the Howard College Campus. Information on the energy usage patterns is vital to informing the way forward for any energy management program. Objectives 1 to 4 provide the information base required for this purpose.

With this information, projected savings could be done on different types of projects and the projects with the most attractive (lowest) simple payback estimation could then be motivated to be implemented. Savings from these initial projects could then be put back into a project, thereby creating a positive cashflow mechanism for the project. For management to have faith in the projected savings model, the accuracy and integrity of these savings model needed to be tested and verified in a live project. Objective 5 in Table 8.1 achieves this objective. The foundation of an energy management program has now been laid. A summary of the results obtained in the previous chapter are given below.

8.2. Summary of Audit Results

The results of the energy audit indicated that the major loads are broken up as shown in Table 8.2:

MAJOR LOADS	PEAK CAPACITIES	CATEGORY
Internal Lighting Load	1 999 kW	Commercial
Unitary A/C Equipment	1 696 kW	Industrial
North Core chilled water system	1 017 kW	Industrial
South Core chilled water system	245 kW	Industrial
Boilers in Residences	672 kW	Residential
Other A/C Plant	466 kW	Industrial
Other Loads	1 450 kW	All

Table 8.2: Installed Capacities of Large Loads

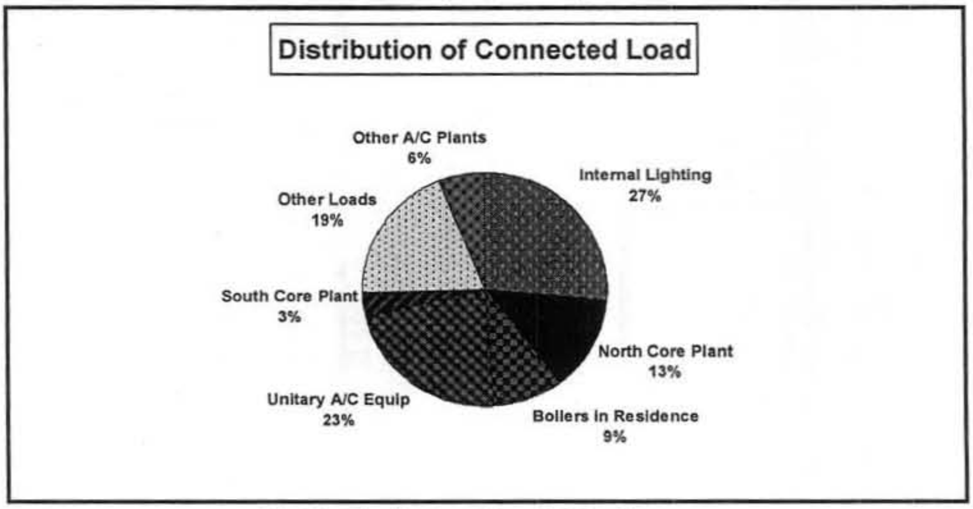


Fig 8.1: Distribution of Installed Loads

As can be seen from Fig 8.1, the total connected air-conditioning load is 3 424 kW. This accounts for approximately 45% of the total connected load. With the climate being subtropical, the air-conditioning requirements are quite demanding.

A summary of the air-conditioning plants are given below:

- There is the North Core Plant. This is a Thermal Energy Storage (TES) system, which uses chilled water to extract heat from the building.
- There is also the Memorial Tower Building (MTB) system, which also uses chilled water, but there is no storage component here.
- The South Core plant is a smaller Thermal Energy Storage (TES) that is used to supply certain buildings on the southern part of the Main Campus.
- Mechanical Engineering has an Air-Cooled Chiller.
- Francis Stock also has an Air-Cooled Chiller.
- George Campbell has a small Ice Plant.

The installed capacity of the HVAC load is 3120 kW with the loads being broken up as follows:

North Core Chiller Plant (Thermal Storage Plant)	1 017 kW
MTB Chilled Plant Water Plant	360 kW
South Core Chiller Plant (Thermal Storage Plant)	235 kW
Mechanical Engineering - Air-Cooled Chiller	54 kW
Francis Stock - Air-Cooled Chiller	48 kW
George Campbell - Ice Plant.	8 kW
Unitary Equipment	1 696 kW
TOTAL INSTALLED LOAD	**3 424 kW**

Table 8.3: Installed Capacities of Air-conditioning Systems

The pie chart above shows that the other major categorised loads are the internal lighting load (1 647 kW) and the boilers in the residences (672 kW).

From the audit it was seen that the attitude towards energy costs was that it was a fixed budgeted cost that escalated every year due to inflation. There was no real effort made to contain these costs. Due to the fact that the facility management maintenance functions in the University is outsourced, and that the energy consumption is directly linked to the facility management, there did not seem to be any inherent ownership of the energy management process. To be fair to the facility managers, although it was a part of their mandate to exercise energy management, there was no real provision made for this in the budget. Therefore to counter this and other observations made during the audit, recommendations are made by the author later on in this chapter.

8.3. Outcomes of Energy Audit

It is possible for the University of KwaZulu-Natal to save on electricity costs, not all of them involve necessarily using less energy. This can be done through a number of means, which are discussed below.

8.3.1. HVAC

The two thermal storage systems greatly reduce the demand component and demand costs. To illustrate this claim, a calculation was performed to evaluate what the energy costs would be in summer for a single chiller plant on a thermal storage system, versus that chiller plant running conventionally. The electrical energy costs for the thermal storage system is in the order of R 40 800.00 per month versus the R 96 000 for the conventional system. This is due to the reduction in demand costs.

The North Core plant currently was designed with the intention of incorporating the Electrical Engineering building onto this system. The Electrical Engineering Building air-conditioning system is at the end of its design life and instead of maintaining this system; this provides an ideal opportunity to transfer this load onto the North Core TES system.

The South Core plant supplies George Campbell and Science Lecture Theatres. The current configuration of the system is to get a temperature difference of 5 °C between the inlet and outlet of the tank. There are two chillers connected in parallel at the moment, and the chilled water goes through two cycles to get a temperature difference of 10 °C. An alternative would be to connect the chillers in series instead of parallel so that the time that the chillers work for are reduced and this reduction in time will allow the off peak period in the tariff to be used as a window for charging the tank.

The number of unitary air-conditioning equipment on campus is also problematic. A policy on the installation and type of unitary equipment for future installations needs to be decided upon and strictly implemented. Control of this load, with the ability to shed these loads for short periods, will also realise substantial savings through reduced demand in the peak and standard energy periods.

An alternative scenario that merits further investigation is the installation of a third thermal energy storage system. This system could be sized to accommodate the Memorial Tower Building, Francis Stock, Durban Centenary Building and possibly the Elizabeth Sneddon Theatre. The facility management staff and contractors have more than adequate experience and knowledge of these systems and therefore the management of a third TES system should not be a problem. In fact it should reduce maintenance costs as 291 window units will be removed from service, thereby removing the annual maintenance costs associated with each of these units. More importantly from an energy point of view, 588 kW of installed window air-conditioning load will be moved to the cheaper off-peak period.

8.3.2. Lighting

The Main Campus has an installed capacity of 1 647 kW of internal lighting. The bulk of these are 2 lamp 58W fluorescent fittings with magnetic ballasts and monophospor lamps. These magnetic ballasts have a large loss component. The power factor and ballast life is also very poor in comparison to electronic ballasts. There is huge potential for savings by simply retrofitting these fittings with modern more efficient fittings, as in the case of the EG Malherbe Library.

There are numerous incandescent lamps throughout the campus. These need to be replaced with compact fluorescent lamps (CFLs) as soon as possible. The advantages of this are a reduction in energy consumption by approximately 80 % as well as improved lamp life. Improved lamp life has the effect of reducing maintenance costs. By purchasing the lamps in bulk, a discount can also be obtained to reduce the unit cost of the CFL. The majority of the lamps used in the residences are also incandescent lamps. It has been reported that there has been problems of theft with regard to implementing this type of technology. A recommended option would be to replace the incandescent lamps with modular fittings operating with PL type lamps to counter the problem of theft.

Current practices, at the University, dictate that the cheapest possible luminaire be installed for either new installations or replacing existing failed lamps/luminaires. By deciding upon a specification and securing price discounts through bulk purchases or negotiated trade discounts with luminaire suppliers, the cost to replace more efficient luminaires for all new and existing projects should only be marginally higher. This marginal cost difference would more than adequately be recovered through reduced energy and maintenance costs. Conservative estimates to retrofit all the existing luminaires, with more modern efficient luminaires, show that the lighting system demand component can be reduced by approximately 600 kW.

8.3.3. Benchmarking

The energy consumption and energy cost per assignable floor area varies for each feeder. Benchmarks need to be developed for each building as the building envelopes. A benchmark of an energy efficient building with a particular building envelope, occupation pattern and usage pattern needs to be developed. All the buildings then need to be "tuned" until it can get as close as cost-effectively possible to its particular benchmark. Guidelines and benchmarks for new structures need to be also developed and followed. The ability to conservatively reduce the base load will realise savings in excess of R 100 000 per annum (2002 costs). This will require an awareness campaign to be instituted at minimal cost and the use of time clocks, to switch of the lighting after-hours in certain areas.

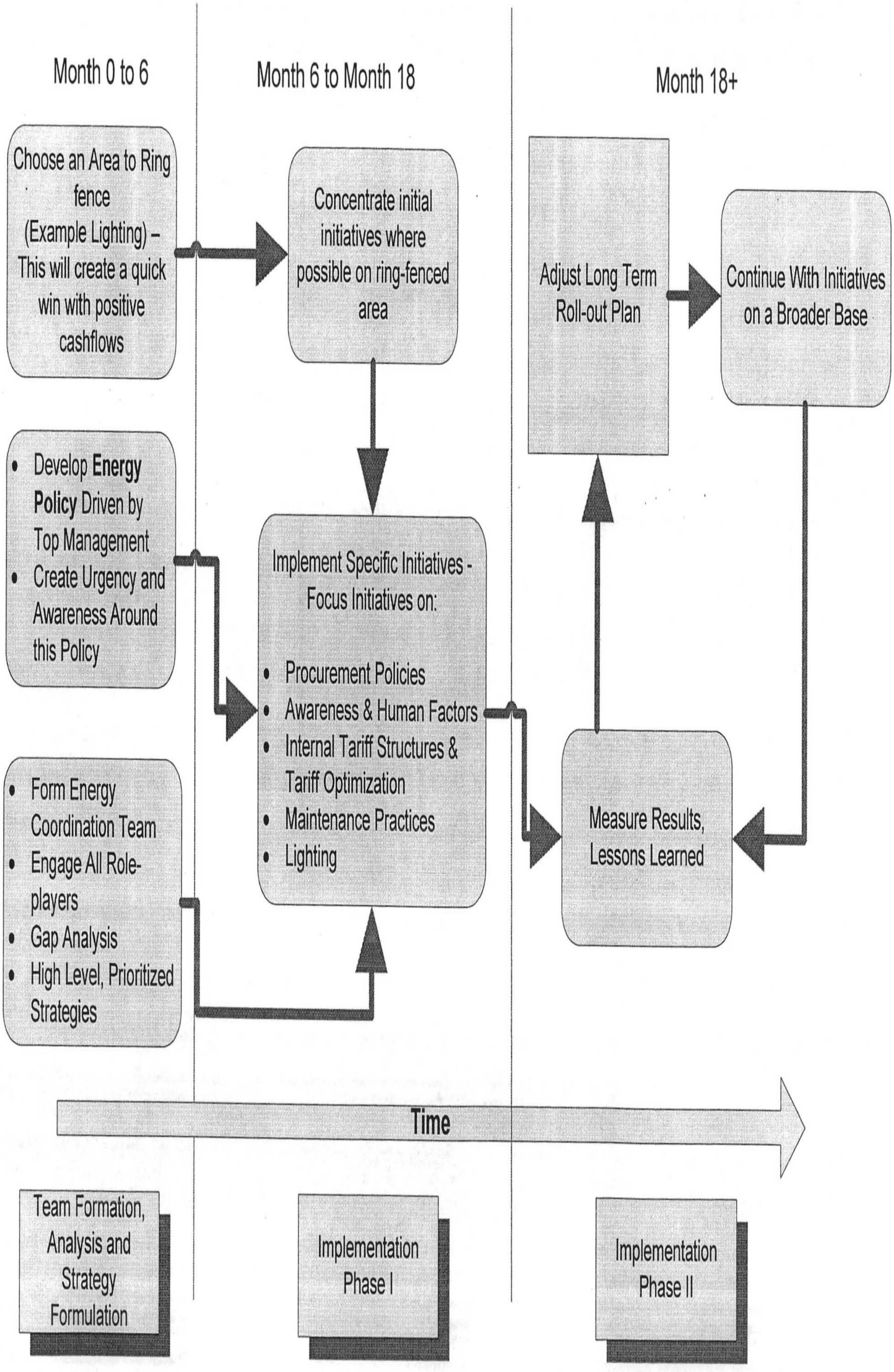
8.3.4. Energy Management System

The University of KwaZulu-Natal, Main Campus has both a Building Management System (BMS) and an Energy Management System (EMS). The audit has revelaed loads that can be potentially shifted without adversely affecting regular campus activities. The BMS and EMS have to be integrated so that the functionality of the two systems can be used to shift load and thereby reduce demand costs.

8.4. Recommendations

Leadership has to be seen to be the starting point of any strategy. It is widely agreed that even the best strategy can fail if an organisation doesn't have a cadre of leaders with the right commitment at the right levels of the organisation. Committed leadership is required to motivate the actions needed to alter the current situation in any significant way. The current situation is that energy management is viewed as a "nice to have" but is really the realm of researchers and cannot be easily incorporated into the normal way of doing business. This has been demonstrated in Chapter 7 to be an incorrect perception. The starting point would be the creation and implementation of an energy policy. This policy must be driven from top management and management must be seen to own this policy. Commitment from management in the form of funding and creating accountability would go a long way to ensuring that this policy is adhered to.

An example of a phase to phase execution of an energy management program driven by an energy policy is shown below.


Month 0 to 6
Month 6 to Month 18
Month 18+
Choose an Area to Ring fence (Example Lighting) – This will create a quick win with positive cashflows
Concentrate initial initiatives where possible on ring-fenced area
Adjust Long Term Roll-out Plan
Continue With Initiatives on a Broader Base
Develop Energy Policy Driven by Top Management
Create Urgency and Awareness Around this Policy
Implement Specific Initiatives - Focus Initiatives on:
Procurement Policies
Awareness & Human Factors
Internal Tariff Structures & Tariff Optimization
Maintenance Practices
Lighting
Measure Results, Lessons Learned
Form Energy Coordination Team
Engage All Role-players
Gap Analysis
High Level, Prioritized Strategies
Time
Team Formation, Analysis and Strategy Formulation
Implementation Phase I
Implementation Phase II

8.4.1. Energy Policy

As discussed in the introduction to this section, ownership of energy costs needs to be introduced. Such as concept cannot be introduced without management introducing and adhering to a policy on energy usage.

An example of a generic energy policy is given below in Fig 8.2.

Note that the above energy policy is indicated as an example of a generic policy that can be used for the UN campuses. A more directed policy must be formulated for consideration by University of KwaZulu-Natal management, after consultation with the relevant stakeholders.

Energy Policy for the University of KwaZulu-Natal

UNIVERSITY OF
KWAZULU-NATAL

Corporate Commitment

Statement of Commitment

We are committed to the following:

- Reduction of our energy cost
- Improving our energy efficiency
- Reducing our contribution to greenhouse gases
- Reducing the environmental impact resulting from our energy usage
- Investing in "green" and energy efficient technologies
- Improving on past trends:

In the next five years

- Our energy costs will be reduced by 10 % (inflation linked)
- Our energy efficiency level must increase by 15%
- Our contribution to Green House Gases must be reduced by 10 %.

Fig 8.2: Generic Energy Policy Statement of Commitment

8.4.2. Identification of a coordinating committee

"An energy management programme that has been completely represented through an energy policy and strategy is only as good as the people who manage it." To this end, he has identified three areas that need to be addressed [5]:

- Energy Co-ordination Committee.
- Energy Manager.
- Energy Action Team.

The energy co-ordination committee is usually made up of a representative sample of the institution community and undertakes the following tasks [5]:

- Ensure the energy management programme remains focussed through acting as the custodian of the energy policy.
- Review the policy annually or on the recommendation of the energy manager.
- Provide an environment in which the energy manager and his or her team can perform their function.
- Represent all components of the institution community.
- Advise the top management of the institution on energy related issues on campus.

It is much simpler to get the message across and to get buy-in if there is representation from all the different groups on the campus. An example of a full representative group is shown in Fig 8.3.

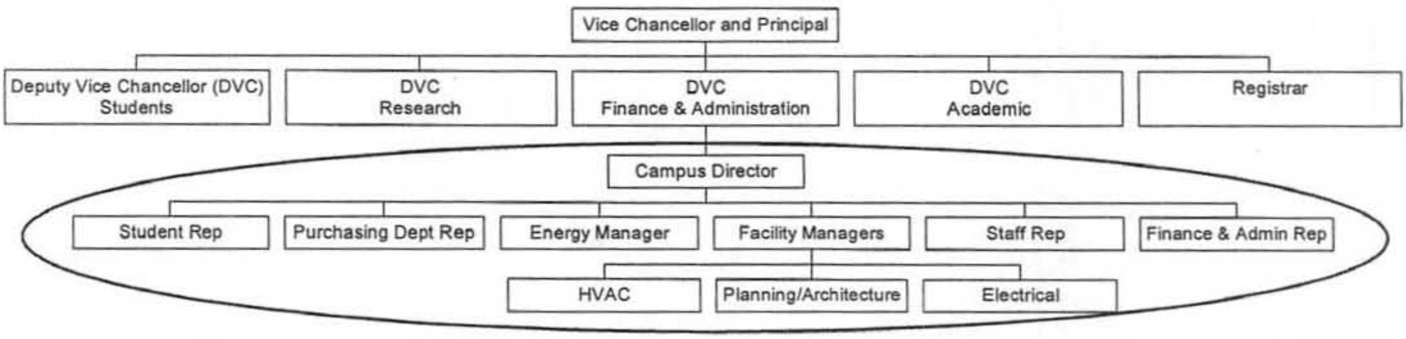


Fig 8.3: Energy Co-ordination Committee

The committee should meet regularly (i.e. monthly) during which the energy manager has an opportunity to pinpoint problem areas that need to be solved by the committee. For this reason, the membership of the committee will depend on the various facets of activities on campus

Typically, the energy co-ordination committee would contain representatives of facilities management, energy researchers, academic staff, students, purchasing departments and finance. The committee reports directly to the top management of the institution through the chairperson (which is this case should be the campus director).

8.4.3. Energy Manager

The energy manager is responsible for achieving the goals and ultimately the mission statement of the energy management programme. For this task he or she receives assistance from an energy action team and the energy co-ordination committee. The energy manager is responsible for the design and implementation of the energy strategy. The post of energy manager should ideally be filled in a full-time capacity although occasionally it will need to be included in an existing manager's portfolio due to resource limitations. The energy manager reports to the energy co-ordination committee on the working status of the energy management programme and their function is to assist and not police his or her actions.

8.4.4. Energy Action Team

It is impossible for a single person to achieve all the tasks in the energy management programme. To this end, the energy manager appoints an energy action team of people who undertake the projects and tasks in the energy strategy. Typical membership includes energy researchers, academic staff, facilities technicians and students. The members of the energy action team are not dedicated positions but assist the energy manager as and when their help is required.

Note that the idea is to not create new positions and new overheads but rather to expand the portfolios of certain existing positions where their existing job functions allows them to make valuable inputs into the energy management programme.

8.4.5. Awareness and Participation of the University Community

The university community's actions contribute to the energy usage pattern. Therefore their involvement and buy-in into the program is vital for the program as a whole to succeed. The awareness of the university community can bring about a substantial energy saving with little or no cost.

As outlined in Chapter 3, an energy management program can be successful only if it arouses the participative interests of people at all levels of the tertiary institution. Ideas should be encouraged with rewards for significant contributions to the energy management program. Staff and students who participate and who feel themselves partners in the planning and implementation of the program will be more inclined to share pride in the results.

Communicating with staff and students on the subject of energy can be accomplished in many different ways: face to face discussion, seminars and workshops, distribution of informative and descriptive literature and most of all, through sincere practice of conservation on the part of management at all times.

The use of newsletters, bulletin boards, email and intranets for illustrating energy conservation objectives and accomplishments will help impress upon staff and students the importance of such matters. Staff and student participation can be increased by communicating examples of energy conservation ideas being implemented, photographs of persons who submitted the ideas, and information on the savings realised.

Competition between faculties, departments or residences within the University in pursuing conservation of energy can also generate enthusiasm among the university community. Competitive programs can be initiated and should be encouraged. Acknowledgment of good ideas and positive reinforcement are keys to this approach. People should be shown why their help is needed, and a team approach should evolve.

A clear, concise list of firm do's and don'ts to guide staff and students in their work can be helpful in achieving energy conservation practices. Such lists should be distributed to all staff and students in the manner prescribed above. These lists should be updated as often as necessary. The feeders that have been analysed have also indicated a higher than necessary baseload for most buildings. This indicates that equipment is being left on unnecessarily. An awareness program along with a follow up report on the impact of this program will assist in reducing this baseload. The cost of the awareness program should be minimal as existing email and IT resources can be used for communication.

8.4.6. Maintenance Policy

As mentioned earlier, the decisions taken by the maintenance personnel on replacement of equipment is a crucial contributor to the energy costs of a facility. Creating a maintenance policy that dictates the type of equipment that should be used in a facility can assist management in attaining the goals set out in the energy policy. This would be a very cost effective option to get a facility to eventually become energy efficient. An example would be replacing failed luminaries with energy efficient luminaries.

8.4.7. Tariff Optimisation

Although the tariff that the main campus currently is on the most optimum of those available, the tariffs should be periodically reviewed to maintain the status quo. An observation that was made (but is outside the scope of this study) is that there are three different electricity accounts for the Durban campuses (excluding Edgewood College). These accounts are for:

- Main Campus.
- Western Campus.
- Medical School Campus.

These campuses are all within a three-kilometre radius of each other and are fed from the same main substation (Congella) of the Council. The Council has indicated a willingness to aggregate these three accounts (as part of a pilot project). There would be immediate savings to the University by virtue of the Medical School and the Western Campus benefiting from the cheaper tariff. The University could also gain by the diversity of these three loads, for load control purposes.

8.4.8. Internal Tariff Structure

One means of motivating energy conservation is to apportion electricity costs to each building or department. Energy costs would then come out of departmental budgets rather than the general University budget. An automatic meter reading system (AMR) is already in place that is metering each transformer on the reticulation system.

Individual metering could also be extended to university residences to motivate students to conserve energy. Many students also have their residence fees paid by bursary, and independent metering would mean that they would have to pay the bill out of their own pockets. It has been suggested that students are given an electricity allocation each month and if they use any more they would have to pay the difference. This issue is obviously sensitive and broad consultation is required before a decision is made.

8.4.9. Office equipment

Office equipment constantly consumes energy. The core function of the University revolves around the use of this equipment, so therefore the only option to save energy in this area is to use equipment that can provide the same or higher levels of service with the lowest energy usage. An established benchmark for energy efficient equipment/appliances is the ENERGY STAR program.

In 1992 the US Environmental Protection Agency (EPA) introduced ENERGY STAR as a voluntary labeling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. Computers and monitors were the first labeled products. Through 1995, EPA expanded the label to additional office equipment products and residential heating and cooling equipment. In 1996, EPA partnered with the US Department of Energy (DOE) for particular product categories. The ENERGY STAR label is now on major appliances, office equipment, lighting, home electronics, and more [69].

Some listed benefits of purchasing ENERGY STAR labeled products are:

- These products use 25 to 50% less energy.
- Reduced energy costs without compromising quality or performance.
- Reduced air pollution because fewer fossil fuels are burned.
- Significant return on investment.
- Extended product life and decreased maintenance.

8.4.10. Energy Procurement Policy

Purchasing efficient products reduces energy costs without compromising quality. Successful energy management programs adopt a procurement policy as a key element for their overall strategy. Instituting an effective policy can be as easy as asking procurement officials to specify approved products, such as office equipment, in their contracts or purchase orders. Dedication to ensuring the success of the program should extend to ensuring that this policy extends to all energy consuming equipment purchased by the University. This will include equipment such as HVAC equipment, light fittings and laboratory equipment.

This policy should also extend to the design and construction of new facilities. Architects should be briefed to design theses facilities so that the building envelope is energy efficient from the outset.

8.4.11. Evaluate Performance

Sustaining energy performance and ensuring the long-term success requires a strong commitment to evaluating performance and progress. Many organizations have found that energy management programs achieve great success in early years but become less effective over time. To avoid this common cycle and to ensure continuous improvement and sustained success, frequent review and evaluation of progress towards goals by staff and senior management are required in order to verify that improvement is being made.

Evaluation and reassessment should not been seen as the final step of the system, but an important and necessary recurring element. Formal evaluation should be an annual event providing feedback for future planning and reassessment of corporate energy performance goals; implementation plans; measuring, tracking and benchmarking; and communication and recognition elements.

The evaluation process involves measuring, tracking and benchmarking to verify that the milestones and goals are being met and desired results, both in terms of energy performance and overall value to the organization, are achieved. As many energy professionals have observed you cannot manage what you cannot measure. The first step to assessing performance was developing the baseline. Good energy management builds on the baseline by tracking progress and benchmarking with peers. Evaluating progress is also a critical step for supporting communication efforts, both internally and externally.

8.5. Further Remarks

From the conclusion of the case studies in Chapter 2 it was concluded that for a successful energy management program at a tertiary institution, the items listed under recommended action is required:

RECOMMENDED ACTION	ACTION LIST
Establishment of an Energy Policy	TO BE DONE
Energy Audit	COMPLETED
Benchmarking of Buildings	TO BE DONE
Installation of meters to monitor energy consumption patterns	COMPLETED
Energy Management and Control System	PARTIALLY COMPLETE
Efficient Thermal Plant, if air-conditioning is a major requirement	PARTIALLY COMPLETE
Motor replacement, where feasible	TO BE DONE
Reduction of energy and maintenance costs on plant equipment	TO BE DONE
Awareness	TO BE DONE
Energy Management Council	TO BE DONE
Improvement of Interior Lighting Efficiency	PARTIALLY COMPLETE

Cogeneration	TO BE DONE

Table 8.4: Action Items for the University of KwaZulu-Natal, Main Campus Energy Management Program

Table 8.4 indicates the items that need to be actioned for a successful energy management program on the Durban Main Campus. Some items have already started receiving attention (indicated as partially complete) and others have received no attention at all. An accelerated effort by management needs to be made to realise the potential for energy savings and cost savings on the Durban Main Campus.

In Africa, very few countries, companies and tertiary institutions have formal energy management programs in operation. With sweeping changes taking place in the Electricity Supply Industry of these countries, companies and tertiary institutions are going to be caught off guard and this will affect their global competitiveness. The energy costs in South Africa have been kept artificially low in the last few years with price increases being kept below the Consumer Price Index (CPI) inflation indicator. There have been indications by ESKOM, with this being demonstrated in 200, that future price increases will be above CPI.

From a tertiary education point of view, cutbacks in government funding have forced tertiary institutions to lower overheads. Energy management is one way for these institutions to cut back on costs.

The energy audit conducted within this study has identified various different areas where savings can be made. To realise these savings a dedicated person/team will need to be appointed to carry this forward.

Energy management has major spin-offs for all players involved. At the rate that the world is advancing and the energy required to sustain economic development, the fuel reserves for power generation will soon be depleted. The options are either to cutback on energy usage or to find alternative clean fuels. Present power generation has a hugely negative impact on the environment and contributes to the greenhouse effect. Energy management makes social, environmental and economic sense.

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Glossary

Air-Conditioning or **Cooling**: Conditioning of room air for human comfort by a refrigeration unit (e.g., air- conditioner or heat pump) or by circulating chilled water through a central cooling or district cooling system.

Ballast: A device used to operate fluorescent and HID lamps. The ballast provides the necessary starting voltage, while limiting and regulating the lamp current during operation.

Base load: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Behavioural Change: As it affects energy efficiency, behavioural change is a change in energy-consuming activity originated by, and under control of, a person or organization. An example of behavioural change is adjusting a thermostat setting, or changing driving habits.

Boiler: A device for generating steam for power, processing, or heating purposes or for producing hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.

Btu (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Candela: Unit of luminous intensity, describing the intensity of a light source in a specific direction.

Candela Distribution: A curve, often on polar coordinates, illustrating the variation of luminous intensity of a lamp or luminaire in a plane through the light center.

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.

Coincidental Demand: The sum of two or more demands that occur in the same time interval.

Coincidental Peak Load: The sum of two or more peak loads that occur in the same time interval.

Colour Rendering Index (CRI): A scale of the effect of a light source on the colour appearance of an object compared to its colour appearance under a reference light source. Expressed on a scale of 1 to 100, where 100 indicates no colour shift. A low CRI rating suggests that the colours of objects will appear unnatural under that particular light source.

Colour Temperature: The colour temperature is a specification of the colour appearance of a light source, relating the colour to a reference source heated to a particular temperature, measured by the thermal unit Kelvin. The measurement can also be described as the "warmth" or "coolness" of a light source. Generally, sources below 3200K are considered "warm" while those above 4000K are considered "cool" sources.

Commercial: The commercial sector is generally defined as nonmanufacturing business establishments, including hotels, motels, restaurants, wholesale businesses, retail stores, and health, social, and educational institutions. The utility may classify commercial service as all consumers whose demand or annual use exceeds some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Commercial Building: A building with more than 50 percent of its floor space used for commercial activities. Commercial building include, but are not limited to, stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings are included except for buildings on sites with restricted access, such as some military bases or reservations. A building is an enclosed structure containing over 1,000 square feet of floor space and intended for human occupancy. Agricultural, industrial, and residential buildings are excluded from commercial sector surveys.

Compact Fluorescent: A small fluorescent lamp that is often used as an alternative to incandescent lighting. The lamp life is about 10 times longer than incandescent lamps and is 3-4 times more efficacious. Also called PL, Twin-Tube, CFL, or BIAX lamps.

Cooling Degree-Days (CDD): A measure of how hot a location was over a period of time, relative to a base temperature.

Demand (Electric): The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, at a given instant or averaged over any designated period of time.

Demand-Side Management: The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shape changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-Side Management (DSM) covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

Distribution System: The portion of an electric system that is dedicated to delivering electric energy to an end user.

Education: refers to buildings that house academic or technical **classroom** instruction. Certain buildings in educational facilities are excluded from this category, e.g., administration (office), dormitory (lodging), gymnasium (assembly), etc.

Efficacy: A metric used to compare light output to energy consumption. Efficacy is measured in lumens per watt. Efficacy is similar to efficiency, but is expressed in dissimilar units. For example, if a 100- watt source produces 9000 lumens, then the efficacy is 90 lumens per watt.

Electric Utility: A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the country, its territories, for the generation, transmission, distribution, or sale of electric energy primarily for use by the public. Facilities that qualify as cogenerators or small power producers are not considered electric utilities.

Electronic Ballast: A ballast that uses semiconductor components to increase the frequency of fluorescent lamp operation (typically in the 20-40 kHz range. Smaller inductive components provide the lamp current control. Fluorescent system efficiency is increased due to high frequency lamp operation.

End Use: Any specific activity performed by a sector (residential, commercial, industrial, or transportation) that requires energy, e.g., refrigeration, space heating, water heating, manufacturing process, feedstocks, etc.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British thermal units.

Energy Charge: That portion of the charge for electric service based upon the electric energy (kWh) consumed or billed.

Energy Efficiency[1]: A value-based, philosophical concept. In this report, two different concepts of energy efficiency are discussed, a technical and a more broad, subjective concept. In the technical concept, increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs. In the more subjective concept, energy efficiency is the relative thrift or extravagance with which energy inputs are used to provide goods or services.

Energy Efficiency[2]: Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption, often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air-conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Energy-Saving Lamp: A lower wattage lamp, generally producing fewer lumens.

Floorspace: The area enclosed by exterior walls of a building, including parking areas, basements, or other floors below ground level. It is measured in square metres.

Fluorescent Lamp: A light source consisting of a tube filled with argon, along with krypton or other inert gas. When electrical current is applied, the resulting arc emits ultraviolet radiation that excites the phosphors inside the lamp wall, causing them to radiate visible light.

Footcandle (FC): The English unit of measurement of the illuminance (or light level) on a surface. One footcandle is equal to one lumen per square foot.

Greenhouse Effect: The increasing mean global surface temperature of the earth caused by gases in the atmosphere (including carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbon). The greenhouse effect allows solar radiation to penetrate but absorbs the infrared radiation returning to space.

Heating Degree-Days (HDD): A measure of how cold a location was over a period of time, relative to a base temperature.

Harmonic Distortion: A harmonic is a sinusoidal component of a periodic wave having a frequency that is a multiple of the fundamental frequency. Harmonic distortion from lighting equipment can interfere with other appliances and the operation of electric power networks. The total harmonic distortion (THD) is usually expressed as a percentage of the fundamental line current. THD for 4-foot fluorescent ballasts usually range from 20% to 40%. For compact fluorescent ballasts, THD levels greater than 50% are not uncommon.

Industrial: The industrial sector is generally defined as manufacturing, construction, mining agriculture, fishing and forestry establishments Standard Industrial Classification (SIC) codes 01-39. The utility may classify industrial service using the SIC codes, or based on demand or annual usage exceeding some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Interruptible Load: Refers to program activities that, in accordance with contractual arrangements, can interrupt consumer load at times of seasonal peak load by direct control of the utility system operator or by action of the consumer at the direct request of the system operator. It usually involves commercial and industrial consumers. In some instances the load reduction may be affected by direct action of the system operator (remote tripping) after notice to the consumer in accordance with contractual provisions. For example, loads that can be interrupted to fulfil planning or operation reserve requirements should be reported as Interruptible Load. Interruptible Load as defined here excludes Direct Load Control and Other Load Management.

Kilowatt (kW): One thousand watts.

Kilowatthour (kWh): One thousand watthours.

Lamp Lumen Depreciation Factor (LLD): A factor that represents the reduction of lumen output over time. The factor is commonly used as a multiplier to the initial lumen rating in illuminance calculations, which compensates for the lumen depreciation. The LLD factor is a dimensionless value between 0 and 1.

Life-Cycle Cost: The total costs associated with purchasing, operating, and maintaining a system over the life of that system.

Load (Electric): The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

Louver: Grid type of optical assembly used to control light distribution from a fixture. Can range from small-cell plastic to the large-cell anodized aluminum louvers used in parabolic fluorescent fixtures.

Luminaire: A complete lighting unit consisting of a lamp or lamps, along with the parts designed to distribute the light, hold the lamps, and connect the lamps to a power source. Also called a fixture.

Lux (LX): The metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter. One lux equals 0.093 footcandles.

Maximum Demand: The greatest of all demands of the load that has occurred within a specified period of time.

Non-coincidental Peak Load: The sum of two or more peakloads on individual systems that do not occur in the same time interval. Meaningful only when considering loads within a limited period of time, such as a day, week, month, a heating or cooling season, and usually for not more than 1 year.

Occupied Floorspace: The area of all commercial buildings excluding those buildings classified as vacant and all other buildings that were more than 50 percent vacant during the three months preceding the survey.

Office: refers to buildings used for general office space, professional offices, and administrative offices.

Optics: A term referring to the components of a light fixture (such as reflectors, refractors, lenses, louvers) or to the light emitting or light-controlling performance of a fixture.

Peak Demand: The maximum load during a specified period of time.

Peaking Capacity: Capacity of generating equipment normally reserved for operation during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on an around-the-clock basis.

Photometric Report: A photometric report is a set of printed data describing the light distribution, efficiency, and zonal lumen output of a luminaire. This report is generated from laboratory testing.

Power: The rate at which energy is transferred. Electrical energy is usually measured in watts. Also used for a measurement of capacity.

Power Pool: An association of two or more interconnected electric systems having an agreement to coordinate operations and planning for improved reliability and efficiencies.

Principal Building Activity: The activity or function occupying the most floor space in the building. The categories were designed to group buildings that have similar patterns of energy consumption

Reflector: The part of a light fixture that shrouds the lamps and redirects some light emitted from the lamp.

Retrofit: Refers to upgrading a fixture, room, or building by installing new parts or equipment.

Residential: The residential sector is defined as private household establishments which consume energy primarily for space heating, water heating, air conditioning, lighting, refrigeration, cooking and clothes drying. The classification of an individual consumer's account, where the use is both residential and commercial, is based on principal use. For the residential class, do not duplicate consumer accounts due to multiple metering for special services (water, heating, etc.). Apartment houses are also included.

Space Heating: The use of mechanical equipment to heat all or part of a building to at least 50 degrees Fahrenheit. Includes both the main space-heating and secondary space-heating equipment, but excludes energy used to operate appliances that give off heat as a by-product

Substation: Facility equipment that switches, changes, or regulates electric voltage.

Task Lighting: The lighting, or amount of light, used for a given task. Task lighting is localized to the visual task.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other non-cooking applications of hot water. An automatically controlled, thermally insulated vessel designed for heating water and storing heated water at temperatures less than 180 degrees Fahrenheit.

Work Plane: The level at which work is done and at which illuminance is specified and measured. For office applications, this is typically a horizontal plane 30 inches above the floor (desk height).

Appendix H

Correspondences and Unpublished Reports

APPENDIX A

Metering Considerations

Presented at the **17th National Industrial Energy Technology Conference & Energy Manager's Workshop** April 5-7, 1995 in Houston, Texas

METERING AND MONITORING APPROACHES FOR VERIFYING ENERGY SAVINGS FROM ENERGY CONSERVATION RETROFITS: EXPERIENCES FROM THE FIELD

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ABSTRACT

This paper describes instrumentation approaches used in the verification of energy savings from industrial and large institutional energy conservation retrofits. Techniques for monitoring electricity, natural gas and thermal energy flows are presented. Insights gained from the actual in-field installation of monitoring equipment are shared and lessons learned are provided.

BACKGROUND

The industrial sector accounted for 37 percent of gross U.S. energy consumption in 1992, or slightly more than the combined gross consumption of the residential and commercial sectors (1). The industrial sector has also proven to be very responsive to price and supply concerns that entered the energy marketplace following the Arab oil embargo of 1973-74. Industrial energy costs nearly tripled between 1970 and 1975 and nearly tripled again between 1975 and 1983. Industrial energy costs have been slowly declining since then. Net (excludes electricity conversion and distribution losses) U.S. industrial energy consumption reached an all-time high in 1973 at 26 quadrillion BTU (1). Industrial energy consumption then steadily declined until the mid-1980s and has been gradually rising since then. Net industrial energy consumption in 1992 was approximately 23.5 quadrillion BTU (1). Electricity's share of net industrial energy consumption has substantially increased in the last 30 years, growing from 7 to 14 percent of total net consumption, primarily the result of an increase in electricity use in manufacturing (2). Coal has shown a corresponding decrease in consumption, however. Petroleum products and natural gas have continued to represent about 75 percent of net industrial energy consumption for the last 20 years (2).

Industrial energy consumption is projected to continue to grow in the future, with industrial electricity consumption rising the most rapidly at 1.7 percent per year (2). Eight industries — food, paper and allied products, refining, bulk chemicals, glass and glass products, cement, iron and steel, and primary aluminium — account for two-thirds of industrial energy consumption and this trend is expected to continue (2). However, energy consumption in the non-energy-intensive industries is projected to grow twice as rapidly as consumption in the energy-intensive industries (2). The growth in industrial output is projected to grow more rapidly than the growth in energy consumption, resulting in a continuing decline in U.S. industrial energy intensity. Industrial energy intensity in 2010 is forecast to be about 6,000 BTU per dollar of output, or about 60 percent of 1970 levels (2).

While historic data suggest that the industrial sector has been very responsive to energy price and supply issues, industrial sector involvement in utility Demand Side Management (DSM) and conservation programs has been mixed (3). While most utilities have commercial and industrial DSM programs, many utility programs apparently avoid process-related measures and focus on lighting, HVAC and motor improvements, which are often dominated by commercial sector customers (3). In fact, many large industrial customers have in the past objected to utility DSM programs, suggesting that they subsidize commercial and residential customers at the expense of industrial customers. This lack of availability of appropriate industrial DSM programs appears to be gradually changing, however.

The historic lack of involvement of industry in utility DSM programs has resulted in a corresponding lack of published studies on the verification of the energy savings associated with industrial energy conservation retrofits (4). Energy savings verification is generally required for DSM program evaluation but clearly would not be required for self-initiated programs. And any data from self-funded energy savings verification studies would likely remain proprietary. The lack of publication has also resulted in a scarcity of published information about procedures, techniques and instrumentation approaches for verifying industrial and large institutional energy savings on an individual campus, plant or measure basis.

The purpose of this paper is to address this lack of published information and share the authors' experiences in installing instrumentation for industrial and large institutional energy savings verification studies. The authors have been involved in the installation of energy savings verification instrumentation in the Texas LoanSTAR institutional building energy conservation loan program since 1989. They have also served as instrumentation specialists for industrial energy savings verification studies conducted by various utilities in the Pacific Northwest. In total, the authors have installed energy savings verification instrumentation in roughly 100 industrial and large institutional facilities including several district heating/cooling and cogeneration facilities.

This paper will not address specific analysis techniques but rather will describe the data collection, instrumentation and monitoring approaches that, in general, can be used to inform various energy savings verification models and analysis techniques. Administrative and Management requirements for energy savings verification projects will be discussed, and instrumentation and monitoring approaches to monitor electricity, natural gas and thermal energy flows at the plant or campus, and building and device levels will be described. Techniques for monitoring process and site environmental conditions, which are related to energy consumption, will also be described, as will various remote data acquisition approaches. Many of the technical recommendations provided in this paper are drawn from the LoanSTAR Monitoring Equipment Installation Manual, which was developed by the authors for the Energy Systems Laboratory at Texas A&M University (5).

ENERGY SAVINGS VERIFICATION PROJECT PLANNING AND ORGANIZATION

From an overall project perspective, the most important techniques that can be employed to create a successful energy savings verification project are solid organization and good documentation. Energy savings verification projects are not extremely complex, but they do involve the organization and management of a multitude of small details. And the lack of management of those details can be the downfall of a project. More verification projects seem to fail for lack of organization and inadequate documentation than for any other reasons. While not every energy savings verification project will be published in a professional journal, each still deserves to be conducted correctly and should be well documented.

An energy savings verification project must begin with a definition of what is to be accomplished, or in scientific terminology, the development of the experimental design. In energy savings verification, the project goal is usually to compare actual energy consumption subsequent to a retrofit with what the consumption would have been if the retrofit did not take place. The project can be as simple as determining the savings from a single adjustable-speed drive retrofit or as complex as an entire industrial process retrofit—the required process is the same. The project definition process usually begins with a conceptual design in which the project goals, objectives and technical approach are identified and documented. It is imperative to know exactly what you want to accomplish and how you want to accomplish it. In essence, an energy savings verification protocol must be established. The protocol is a standardized project planning and implementation methodology (6).

From a project definition perspective, energy efficiency retrofits can be categorized into at least three general classes (7). The simplest type of load to be verified is non-interactive and highly scheduled. These loads operate at the same energy intensity over well-defined operating periods. The replacement of mercury vapour parking lot lights operated by a time clock with high-pressure sodium lamps or the installation of a microwave drying process that operates at a constant energy level on a constant schedule are examples of this class of load. Engineering calculations without in field metering and monitoring may be sufficient for this project class. Next in complexity are loads that are non-interactive but with a variable schedule. An adjustable-speed drive for a pump or fan where the working fluid does not interact with other thermal loads is an example of this type of load, which can often be verified with simple device level monitoring. The most complex type of loads to be verified are characterized as interactive. These are loads in which a change in one end use influences another. The installation of energy-efficient lamps and fixtures for lighting in conditioned spaces where the reduction in heat loss affects the HVAC system is an example of an interactive load. This class of project may involve monitoring of loads beyond those directly affected by the retrofit. Energy savings verification protocols are thus frequently custom-designed to meet the specific requirements of the project.

The important point to remember is that the first and most crucial step in the energy savings verification process is the establishment of the project design and the development of savings verification protocols, including the design of all data collection forms required for the project. If this foundation is inadequately laid, it would be unreasonable to expect the resulting project to be successful.

A significant project issue that is usually addressed at the project design and protocol development stage is the trade-off between measurement cost and precision and accuracy. Monitoring equipment is expensive to purchase and install. Data analysis is likewise expensive. It is not cost-effective to purchase expensive electric end-use monitoring equipment to verify energy savings from a project that can be verified with reasonable accuracy using engineering calculations. On the other hand, it is probably not worth the time to do an engineering calculation if the result may vary from reality by a factor of two and the accuracy of the calculation can only be increased by appropriate metering. A common rule of thumb for large projects is that metering costs should be in the range of 3 to 5 percent of total retrofit costs. In special circumstances (case studies, highly replicable projects, etc.), metering costs of up to 10 percent of retrofit costs are not considered unreasonable. Metering projects are typically most cost-effective if equipment costs can be spread over multiple retrofits or equipment can be used for subsequent projects.

ENERGY SAVINGS VERIFICATION PROJECT IMPLEMENTATION

An Initial Site Inspection (ISI) is usually the first step in energy savings verification project implementation. The initial site inspection involves a tour of the facility, during which retrofit locations are inspected and information is collected to help develop the project measurement plan and refine project cost estimates. Cost estimation is frequently an iterative process. A cost estimate is prepared based on information collected during the ISI using the project design and measurement protocols as guidelines. The estimate is then frequently adjusted based on the realities of budget constraints. The ISI tour should address the following:

- Inspection of the general areas where monitoring might take place;
- Location of major pieces of equipment that will receive retrofits;
- Feasibility of each desired monitoring point;
- Potential equipment mounting or measurement points;
- Presence of existing utility and facility meters;
- Alternate methods of monitoring where necessary; and
- Service entrance information for all pertinent energy types.

It is important to record as much detail as possible during the tour. In complex facilities, you may wish to record your tour with a video camera to aid in recalling monitoring locations when cost estimates and measurement plans are developed.

The development of a Measurement Plan follows the initial site inspection and is such an essential part of the energy savings verification process that it is typically considered a separate step in the project implementation process. The measurement plan is developed from the information collected during the ISI. The measurement plan identifies all monitoring points, specifies sensors and sensor locations, identifies signal and communications cable routes and specifies all other documentation required for monitoring equipment installation. It becomes the formal monitoring plan and contains final project cost estimates. Development of the measurement plan requires careful attention to detail and thorough documentation. The measurement plan is the basis for equipment installation and data analysis and serves as a guide when equipment removal or maintenance is required. Monitoring equipment is ordered, subcontractors secured, and the equipment installation coordinated with the facility based on the measurement plan. It is the central piece of project documentation on every energy saving verification project, no matter how simple or small, should be based on a measurement plan.

ELECTRICAL MONITORING

Measuring the electrical energy use of a building, industrial process or device requires a meter that measures and records the amount of power used over a period of time. Utility revenue meters, watt-hour transducers and multi-channel, integrated, solid-state, watt-hour meters are all used to measure electrical energy consumption for savings verification purposes. Hand-held or portable wattmeters are also used to obtain instantaneous power measurements, which can serve as input to engineering models used to estimate electrical energy consumption.

All of these types of instruments can provide accurate and dependable electrical energy monitoring data. However, care must be taken to ensure that the selected meter produces a measurement that is suited to the application. For example, many hand-held "Amp clamps" are not true RMS and may not produce reliable results on circuits with harmonics. Other solid-state power meters have produced questionable measurements for adjustable-speed drives. The choice of which meter to select depends on the class of energy efficiency retrofit, the characteristics of the individual site and the available budget. The final meter selection decision is usually made during measurement plan development.

Portable Watt Meters

True RMS meters are available in the $400-$1200 price range. In addition to their use for "one-time" measurements to inform engineering models, they are frequently used as a comparison standard when verifying the output of other metering systems. Very sophisticated and highly accurate poly-phase portable power meters are also available in the $5,000-$12,000 range. These meters typically have both recording and display capabilities and are often used for harmonic and waveform analysis. When selecting a hand-held wattmeter, try to select an instrument with as thin a current probe as possible. Thick and bulky current probes are difficult to manoeuvre and operate in crowded electrical panels. Watt probes can also be dangerous to operate. Most have alligator clip style potential terminals. If a voltage clip should become disconnected and go to ground inside an electrical panel, a serious electrical fault will occur and major power disruption and possibly physical injury could result. Do not over-reach when using a watt probe.

Electrical Monitoring Using Multi-Channel Data Loggers With On-Board Electronic Watt Meters

Several firms now offer multi-channel remote data acquisition systems with on-board wattmeter capability. These systems function both as a data acquisition system and as a wattmeter. Sixteen channels of wattmeter capability is a common configuration, and system costs are in the $2,500- $5,000 range excluding sensors. Each channel represents a phase-to-phase or phase-to-neutral power measurement. Electric power measurements are computed in the data logger as the real time product of voltage and current. Current transducers (CTs) and potential transducers (PTs) are the required sensor inputs for this metering system. CTs range in cost from \$30-\$150 each, depending on size and current rating, and are installed on the current-carrying conductors of the loads to be monitored. The primary sides of the PTs (\$50-\$175 each) are installed on the same voltage source used by the loads being monitored. It is necessary to maintain the correct phase relationship between the current and referenced voltage in all electric metering. This means that the conductor on which any CT is installed must be traceable to the same phase that is referenced for voltage at the PT. Furthermore; the data acquisition system must be programmed to identify the correct phase of the associated PT. Some data acquisition systems can accept more than one input voltage source, which provides even more flexibility as well as room for error. Phasing mistakes are among the most common electrical metering installation errors.

CTs can be terminated directly to the data logger, combined in parallel to the data logger or combined in parallel through summing modules or electric "combiner boards" to the data logger. This "daisy chain" approach to connecting CTs greatly increases the capacity of data loggers to monitor multiple electrical loads since several CTs can provide input to a single channel, which represents a single phase of the combined load. Some multi-channel data acquisition systems with on-board watt measurement capability use shunted CTs, which produce a mV output at mA current levels, rather than the 0-5 Amp output CTs that are common in utility metering. The 0-5 Amp CTs can induce dangerously high voltages if placed in an "open circuit" mode around an energized conductor and special care must be exercised in their installation. CTs are available in both split-core and solid-core designs. While solid-core designs can sometimes be more accurate, split-core designs are usually preferred because they can be installed by clamping the CT around the conductor rather than removing the conductor from its termination point to slip the CT over it.

Multi-channel wattmeter data acquisition systems are most cost-effective in installations with multiple loads to be monitored or when only "short-term" monitoring is required. Many multi-channel wattmeters are designed to be "portable" so that they can be used in a short-term monitoring project at one site and then moved to another, allowing their cost to be amortized over more than one project. Installation labour requirements for these systems vary, but even simple installations will require about 4-8 hours each for an electrician/field engineer team to install the monitoring equipment and verify its operation. More complex installations with many CTs per channel and long cable runs could require 3 days or more for the installation team to install and verify the equipment.

Electrical Monitoring Using Watt-Hour Transducers

Watt-hour Transducers (WHT) are individual electronic power meters. Their output can be configured as either a digital (pulse) or an analogue signal, and they can be connected to just about any data acquisition system. Many are designed with local displays so that visual data is available at the meter location. WHTs require CT and reference voltage inputs. PTs usually are not used, which means that line voltage is present at the meter. (Be sure that the enclosures containing such devices are appropriately labelled.) WHTs are available with both standard and shunted CT inputs. The use of shunted CTs is particularly convenient when WHTs and multi-channel data loggers with on-board watt-hour meters are used on the same job. The CTs are then interchangeable.

WHTs are used in applications where only a few electrical measurements are required and in applications where a few more electrical loads need to be monitored than can be connected to the channels available in a multi-channel watt-hour meter. WHTs provide data only about the total load being monitored. Data is not available on an individual phase basis as is the case with multi-channel watt meter/data acquisition system combinations. Because of the nature of their installation, WHTs are normally used in long-term monitoring experiments. WHTs normally cost in the $400-$600 range excluding CTs, and could require 2-4 hours for a field engineer/electrician team to install and verify. One of the major variables influencing WHT installation costs is the difficulty in supplying line voltage to the transducer.

Electrical Monitoring Using Utility Pulse-Initiating Meters

This approach is appropriate when an existing utility meter can provide useful information for energy savings verification. Here, a utility meter is retrofit with a pulse initiator or, if a pulse initiator is already present, a pulse splitter is installed to share the utility signal. The digital signal from the retrofit meter is then routed to a data acquisition system. Each pulse represents a specific number of kilowatt-hours. This approach obviously requires the cooperation of the local utility. It has been the authors' experience that such cooperation can almost always be obtained, but utilities frequently have a longer planning horizon than metering project managers, and adequate coordination time must be reserved. The cost of a utility electric meter retrofit is frequently in the $300-$500 range, with the work normally being conducted by utility personnel. There are also photo-sensing devices on the market that can be affixed to the glass cover of an electric meter and used to sense the rotation of the black mark on the meter disc and ultimately kilowatt-hour consumption. These inexpensive sensors do not require utility involvement in their installation, but utility permission for the sensors use should still be obtained since they are installed on the utility's meter.

NATURAL GAS MONITORING

Existing utility natural gas meters can be fitted with pulse initiators or pulse splitters just like electric meters, and the resulting pulse can be routed to a data acquisition system. Each pulse represents a specific number of cubic feet of natural gas. Again, the cooperation of the utility is required. Retrofit costs in the \$300-\$500 range seem typical. The previously described external photo-sensor is also an option for gas metering.

If natural gas measurements are required where a meter is not currently present, there are two obvious choices: a new meter can be installed or a proxy measurement can be made. Reasonably priced (\$100-\$200), compact, pulse- initiating gas meters are available in the 100 cubic feet-per-hour range, but a large temperature and pressure corrected gas meter, which might be required for an industrial application, can cost \$1,500 or more. Installation labor is another consideration in natural gas monitoring. While a small in-line gas meter can be installed by a skilled plumber in an hour or so, the installation of a large industrial meter may require significantly more time.

Proxy measurements involve the monitoring of an alternate variable in place of the one of direct interest. For example, the operating time of the fan on a natural gas-fuelled, forced-air furnace can be monitored as a proxy for natural gas consumption if the firing rate of the furnace is known or measured. Such an approach obviously would not work for a device with a variable consumption rate. Proxy measurements may involve an accuracy loss, but they can provide substantial cost and efficiency savings. (In the forced-air furnace example, the fan typically runs after the furnace has finished firing.) A run-time sensor can cost as little as \$50 and single-channel run-time data loggers cost as little as \$100-200 and are very simple to install. Heat- or flame- detection sensors are also used in proxy measurement of natural gas combustion. The critical component in the proxy measurement approach is measurement or estimation of the firing rate of the device.

THERMAL MONITORING

Thermal monitoring is a measurement approach that is often considered in industrial energy savings verification, particularly when the data has production or operations and maintenance (O&M) value as well. While some non-intrusive measurement techniques are available and suitable for short-term monitoring, most thermal monitoring approaches involve substantial construction and are appropriate primarily in long- term monitoring schemes. There are reasonable thermal monitoring techniques available for hot and chilled water, steam, steam condensate and boiler feedwater. The approaches described here were generally developed to support the Texas LoanSTAR energy conservation program and have been used to evaluate district heating and cooling and cogeneration systems. None of the thermal metering approaches described here can be considered inexpensive, but from a cost-effectiveness perspective, the information that thermal monitoring provides can be extremely valuable. Thermal measurements are often made at the service entrance unless a consumptive use is involved. In that case, measurement is typically made at the individual device.

Hot and Chilled Water Thermal Monitoring

Thermal monitoring of hot or chilled water involves the measurement of heat transfer. This heat transfer can be to an industrial process, a building or, in the case of a cogeneration or district heating plant, to an entire campus. Chilled or hot water thermal monitoring consists of the measurement of a fluid flow rate and a temperature differential across a thermal load. These measurements can serve as input to a BTU/flow totalizer, which produces a digital pulse output that can be directed to a data logger. Each pulse represents a specific number of BTUs transferred. BTU/flow totalizers usually also have a resetable local display. As an alternative approach, many data acquisition systems have the capability to do real-time mathematics and, hence, can calculate heat transfer in software directly from the flow and temperature data.

After some trial and error, a hot and chilled water BTU monitoring approach was developed by the Texas LoanSTAR building energy conservation program and is now generally recommended by the authors. This approach involves the use of an insertion-type tangential paddlewheel meter, which can be installed directly into a pipe without draining the system using a hot tap approach. Flow is measured by counting the rotations of a tangential rotor in a flow stream. The flow meter should be installed in a location with 10 pipe diameters upstream and 5 pipe diameters downstream of straight, unobstructed pipe to allow full development of the flow profile. Thermistor temperature sensors are used to monitor both the supply and return chilled water lines. The sensors are installed directly into the pipe using a hot tap procedure. One temperature sensor is usually installed in the same general location as the flow meter to simplify installation. Signals from the flow and temperature sensors are routed to a BTU/flow totalizer, which provides digital pulse signals for both flow (gallons) and BTUs, which can be accepted by a wide range of data acquisition systems.

This hot or chilled water BTU monitoring system can be installed for about $3,500 including pipe reinsulation, and no outage is required. Overall accuracy of this system can be maintained in the 2-5 percent range with periodic recalibration of the flow meter. Installation depth is probably the critical factor affecting the accuracy of an insertion-type flow meter. Be sure to carefully follow the manufacturer's instructions. The LoanSTAR program has developed a nomograph to guide the installation of insertion-type flow meters.

Pipe insulation can be a significant issue. Asbestos is common in older pipe insulation, and its presence must be determined prior to any disturbance of the insulation. If asbestos is present, it must be abated before the monitoring equipment is installed.

Condensate and Boiler Feedwater Meter Installation

Axial type, in-line turbine flow meters have been successfully used in the LoanSTAR program to measure both steam condensate and boiler feedwater. These flow meters have a digital pulse output, which can be accepted by a wide variety of data acquisition systems. Each pulse represents a specified number of gallons. Accuracy in the 2-5 percent range can be expected.

Condensate and boiler feedwater meters are normally installed in a trap configuration with a three-valve bypass so that it can be removed for service without causing an outage to the facility. The metering station must be installed in a straight, horizontal section of pipe with a minimum of 5 pipe diameters of straight, unobstructed pipe upstream and 5 pipe diameters downstream from the sensor to allow full development of the flow profile. Approximately 5 to 8 feet of pipe must be cut to install the metering station with the trap bypass. The trap bypass system can be prefabricated to minimize outage time. As was noted previously, the presence of asbestos pipe insulation can be a significant issue. Be certain that asbestos is not present before removing any pipe insulation. The total installed cost of a typical condensate metering station will probably be in the $3,000-$3,500 range. Maintenance should not be a significant issue unless steam surges are present in the condensate flow. High-temperature steam can melt the internal parts of the flow meter.

Steam Metering

Steam metering has typically been avoided in the LoanSTAR program. We have found it to be both cheaper and easier to measure steam condensate and/or boiler feedwater for most heat transfer applications. Steam metering may be required for some consumptive use applications, however. One steam metering approach, with an installed cost in the $4,000 range, is the use of a strain gauge target meter system. These meters are available in insertion and in-line styles. Output from the flow meter, a temperature sensor and a pressure transducer (if the steam is not saturated) are routed to a BTU/flow totalizer. Output from the totalizer is a digital pulse or analogue signal, which can be accepted by many data acquisition systems. An outage and line depressurisation is required for the installation of this metering system so installation scheduling becomes a significant issue. The potential presence of asbestos pipe insulation is also an issue for consideration. It has been our experience that facilities often avoid steam metering because of the potential difficulties involved.

MONITORING TEMPERATURE, RELATIVE HUMIDITY AND MISCELLANEOUS PROCESS CHARACTERISTICS

The measurement of ambient or process temperatures, relative humidity, site environmental conditions and process variables such as pressure or rotational speed are sometimes required for energy savings verification. Most of these sensors provide an analogue output (0-5 VDC, 4-20 mA, etc.), and most are relatively easy to install. Their major requirement is the use of a data logger that accepts analogue signals. An analogue board is an extra cost item for at least one common multi-channel data logger with on-board watt-metering capability. On the other hand, many data loggers designed specifically for analogue inputs do not have on-board watt-metering capability; therefore, the choice of a data logger when these measurements are required is an issue.

There are a multitude of analogue sensors that can be used in energy savings verification studies. One of the most important issues related to sensors of this type deals not with the sensors themselves, but rather with their location. Measurements of temperature, relative humidity and site environmental conditions are often required to be representative of an entire building or site. A sensor may provide a highly accurate measurement but may be located such that the data it provides is unrepresentative of the site. Ambient outdoor temperature or relative humidity sensors located near a building exhaust fan are examples of unrepresentative locations. An outdoor temperature sensor located so that it is exposed to direct sunlight for a certain period of the day during parts of the year is another example of an unrepresentative location. Extreme care must be used when locating sensors required to be representative to ensure that they do indeed represent the intended location.

DATA ACQUISITION SYSTEMS

The data acquisition systems used for energy savings verification vary with the retrofit being monitored and the length of the monitoring period.

Single-channel data loggers have been developed in recent years and are now in common use. These devices are often used in short-term monitoring projects, but their application is by no means restricted to this category of project. Single-channel data loggers normally have a sensor connected to a microprocessor-based data-recording device. The most common single-channel data loggers are the so-called lighting loggers in which a photocell is used to measure the operating period or "on-time" of a lamp. The simplest lighting loggers, which provide cumulative "on-time" only, cost in the range of $100. More complex models that provide date- and time-stamped hours of operation have an on-board memory and cost $300-$400. Other "on-time" or "run-time" single-channel data loggers include current loggers that sense whether an electric current is present in a wire and motor loggers that use an inductive sensor to detect the magnetic field generated by an electric motor or other electrical device.

Multi-channel data loggers are also readily available. These instruments are found in various channel configuration ranges for 1-16 or more channels. They range in complexity from dedicated loggers, which accept only a single form of input such a temperature or relative humidity signal from a specific sensor, to more generic models that accept analogue inputs in most industry standard forms (4-20 mA, 0-5 V etc.). Most of these devices require some type of interface with a laptop computer to download data. Some, in fact, serve only as an input device to a laptop computer and have no stand-alone data-storage capability. A single-channel temperature logger with a simple integrated circuit temperature sensor may cost in the $100 range. The typical cost of a 4-channel generic data logger might be in the $400-$1,000 range. They are used in both short- and long-term energy savings verification measurements.

Multi-channel data loggers with power measurement capability are the most complex type of data loggers used in energy savings verification studies. These devices typically have 8-16 or more channels of power measurement capability and frequently digital and analogue input capability with each power channel representing a phase-to-phase or phase-to-neutral power measurement. Their application and use for electrical measurements has been previously described. They are very versatile and reliable instruments and can be used in both short- and long-term studies. When their cost can be amortized over several projects or long-term applications for the data they provide can be identified, their use should be encouraged.

SUMMARY AND CONCLUSIONS: LESSONS FROM THE FIELD

Murphy's Law (If something can go wrong, it will go wrong) is alive and well in the field of energy savings verification. Metering is not a trivial field of endeavour and mistakes happen. It has been our observation that many, if not most, mistakes result from failures in three areas: organization, supervision and verification.

We have found that project documentation is absolutely critical. From original project planning and measurement plan development, through equipment installation, and on through project maintenance and equipment removal, the discipline and organization provided by thorough project documentation is invaluable. It is the authors' practice to develop a set of forms that address the various aspects of project documentation as one of the first project planning steps. A notebook for each individual monitoring project is then kept. In addition to such obvious data as the project measurement plan, the notebook would contain information such as the name and telephone numbers of facility contacts, signal cable guides and the location of all equipment. Information that is clear in your mind today can be beyond recall when you need it three years from now for a maintenance visit.

Adequate project supervision is just as critical as documentation. Because of the expense involved, it is tempting not to have a field engineer on-site during the entire equipment installation process. It seems so simple to provide the necessary instruction to the appropriate contractors and then come back at the end of the installation phase to tie the monitoring system together and complete the installation. What usually happens, however, is that the engineer spends more time trying to repair the mistakes made by the unsupervised contractors than if the engineer was present on-site throughout the projects. And what is worse, some mistakes made by the contractor may never be found, and the data generated by the monitoring system will be incorrect.

Verification helps to minimize the possibility that the data generated by the monitoring project will be incorrect. All sensors need to be double- checked to make sure they are installed correctly. CTs are sometimes installed with the polarity reversed, and if many CTs are combined together, a reverse-polarity CT is difficult to identify. The best way to prevent reverse-polarity CTs is to have a field engineer work with the electrician installing the CTs to make sure that the proper polarity is established and to verify through measurement that the polarity is correct while the electrical system is still open and the CTs are exposed. The output of every sensor, totalizer and data acquisition system should be verified against a standard prior to completion of the installation. Temperature and relative humidity sensors can be compared to hand-held instruments, watt meter channels can be compared to hand-held watt probe readings and so on. Total verification of the system is essential. Energy savings verification projects often involve the investment of many thousands of dollars. It is incumbent on the project manager to ensure that investment is made wisely.

In general, it is not the complexity of metering projects that results in difficulties. Rather, it is the multitude of small details that must be properly organized and carried out. If the organization is successful, the project will likely succeed.

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APPENDIX B

The Six Equipment Audit Categories

The ensuing sub questions direct attention to possible energy savings. This is not a comprehensive list, but it will be helpful in elevating an awareness of energy waste and conservation opportunities.

1. Lighting

The first item that gets attention is lighting because of its visibility. Key efforts in analyzing and considering lighting from a conservation standpoint are noted below. It is wise to make checks both day and night.

a) Is the light intensity sufficient for the task? [(160 - 450 lux) for halls; (750-1 100 lx) for detailed work.]
b) Is the luminaire proper for directing the light where it is needed?
c) Is the reflection good?
d) Is the color right for the task?
e) Is the luminaire too high or too low?
f) Can task lighting be used effectively?
g) Is good use being made of available natural light?
h) Can desks or machines be grouped by task light required?
i) Are lights and luminaires cleaned periodically?
j) Are lamps turned off when not in use?
k) How many luminaires can be turned off by a single switch?
l) Who turns the lights off?
m) Who uses the space and how often?
n) Can a different, lower wattage lamp be used in the fixture? Do the surfaces reflect or absorb light?
o) Are the luminaires strategically located?
p) Does the luminaire location cause glare?
q) Can lighting be used to beat?
r) Can more efficient light sources be used?
s) Can timers or photocells be effectively used?

2. Heating, Ventilation and Air Conditioning (HVAC)

Key factors in evaluating and better utilizing the HVAC system are as follows:

a.) Are there obstructions in the ventilating system?

- Do filters, radiator fins, or coils need cleaning?
- Are ducts, dampers, or passages and screens clogged?

b.) Is the wrong amount of air being supplied at various times?

- Are dampers stuck?
- Is exhaust or intake volume too high or too low?
- Are all dampers functioning in the most efficient manner?

c.) Can the system exhaust only the area needing ventilation?

d.) Can the system intake only the amount required?

e.) Can air be recycled rather than exhausted?

f.) Can the intake or exhaust be closed when the facility is unoccupied?

g.) Can the system be turned off at night?

h.) Is the temperature right for the area's use? [A 40-50'F temperature may be acceptable for storage.]

i.) Can temperature setback be used effectively?

j.) Will an adjustable speed drive he more efficient?

k.) How many fixtures can be turned off by a single switch?

l.) Is solar energy being effectively utilized?

- Light, but minimum heat in summer
- Light and beat in winter

m.) Can waste heat be used?

n.) Are belts properly tensioned?

o.) Are pulleys and drives properly maintained and lubricated?

p.) Is the refrigerant proper?

q.) Can heat be redirected?

r.) Is the proper system being used?

s.) Is there too much or too little ventilation?

t.) Can the natural environment be used more effectively?

u.) Are doors, windows, or other openings letting out valuable heat?

v.) Can weather-strip, caulking, or other leaks be repaired?

w.) Can additional insulation be justified?

x.) Can all hooded exhaust systems have their own air supply or can they be used as part of the exhaust requirement for the building?

y.) Is the blower cycled or run continuously?

3. Motors and Drives

a) Does the motor match the load?
b) Can the motor be stopped and then restarted rather than idled?
c) Is the motorized process needed at all? Can it be done manually?
d) Who lubricates the motor and associated drives? Is this done at the proper intervals?
e) Can motor beat be recycled?
f) What type of drive is used? Is it the most efficient?
g) What is the voltage and is it balanced?
h) Can the motor be cleaned to lower heat build-up?
i) How is load adjusted?
j) Will two (or more) motors in tandem work better?
k) Is the motor well maintained and in good condition? Are there any electrical leaks to ground? Is the motor in a wet environment?
l) Who turns the motor off and on? How often?
m) How efficient is the motor?

4. Processes

Normally, processes rely heavily on motors, but there are other electrical parts. Process heating is probably the most common non-motor electric process load. The following questions point to areas where improved efficiencies can be made:

a) Can equipment or processes be grouped together to eliminate the transportation of the equipment or material in process?
b) Is the temperature too high?
c) Does heat escape? Can insulation he used effectively?
d) Can the heated energy be recirculated for comfort, process heat, or cogeneration? Can it be exhausted for summer comfort?
e) Is preheat required?
f) Can the process be staged or interlocked
g) Is the product heated, cooled, and then reheated again? If so, a continuous process may be appropriate.
h) Can the processes be lined up for more effective use of equipment?
i) Are the drives, bearings, etc. correctly lubricated?
j) Can the conveyer system be eliminated or modified?
k) Can hot areas be isolated from cold areas?
l) Is one large motor or many small motors better?

m) What equipment can be switched off at night?

n) Would two or three shifts be more efficient?

o) Is any equipment kept idling rather than switched off when in hold or waiting?

p) Are screens cleaned and dampers checked for proper operation of pollution controls, and are they maintained at proper intervals, etc.?

q) Is compressed air made in two or three stages? Is a storage tank being used and is pressure too high?

r) Is process water too hot?

s) Can fluid be recirculated?

t) Is the fluid cooled too much?

u) Is the hot water heater close to where the hot water is needed?

v) Is the process exhaust higher than required for safety or quality, or both?

w) Is hot and cold piping insulated where appropriate?

x) Is temperature controlled so that only necessary beat is added?

y) Is heat supplied or added at the point of use or is it transmitted some distance?

5. Other Electrical Equipment

There is a significant amount of electrical equipment that is taken for granted or rarely noticed. The list below contains some key questions regarding efficiency.

a) Are the transformers required?

b) Is the transformer too hot?

c) Can the transformer be turned off when not in use?

d) Are wiring connections tight? (Improper voltage, unbalanced voltage, and excess heat can result from a bad connection.)

e) Can heat from the switchgear room be utilized? (Remove this heat during the summer.)

f) Are voltage taps in the proper position?

g) Are heaters applied properly?

h) Can heaters be switched off at times?

i) Are contactors in good working order?

j) Is equipment properly bonded and grounded?

k) Are conductors sized properly for the load?

l) Is the power factor too low?

6. Building Environmental Shell

The list below is applicable to electrically heated buildings and also where other energy sources are used.

a) Is allowance made for transition from cold to hot areas and vice versa with an air curtain or vestibule?
b) Can a windscreen keep air infiltration down?
c) Is the proper level of insulation applied?
d) Can full advantage of solar heat be taken? (Remove solar beating effect in summer.)
e) Is automatic door closing appropriate?
f) Can covered loading and unloading areas be utilized to keep heat in?
g) Is it possible to caulk, weather-strip, glaze, or close-off windows?
h) Can double- or triple-pane glass be used?
i) Is a small positive pressure used to keep out drafts?
j) Can areas be staged in progressively cooler or warmer requirements?
k) Would an air screen, radiant heater, etc. be more effective?
l) Are dock seals used on overhead doors?

RECORD OF ENERGY ACCOUNTS for Year						TABLE 1
Month	Total Energy Consumption (kWh)	Maximum Demand kVA	Other Energy Sources	Monthly Energy Consumption (MJ)	Monthly Energy Costs	Monthly Energy Costs using a base Year
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						
Total						

Conversion factors to calculate energy in MJ

Electricity	= 3.6 kWh/MJ
Coal	= 24 MJ/kg
Diesel	= 41 MJ/litre
Liquid Petroleum	= 27.4 MJ/litre

MAINTENANCE AND GENERAL IMPRESSIONS						**TABLE 2**
Equipment:		Specific Problem				
Air Circulation:		Vibration	Isolation	Dirt	Paint	General
Cooling:						
Pumps and Cooling Towers						
Lifts and Escalators						
Transformers and Electrical Equipment						
Heating						
Lighting						

Maintenance Costs						
Equipment	Costs in Rands					
Year	19	19	19	19	20	20
Electrical						
Mechanical						
Lifts and Escalators						
Total						

Comments Regarding Maintenance

Chillers:

Boilers:

Lighting:

Electrical:

Water Treatment:

Control System:

Complaints:

EQUIPMENT LIST FOR BUILDING:									TABLE 3
Floor: ________					Plant Room: ____________				
Reference	Energy Source	Description	Name Plate Power (kW)	Maximum Power calculated or Measured (kVA)	Power Factor Measured	Load Factor	Total Operating Hours per annum	Contribution to Maximum Demand of Building (kVA)	Calculated Energy Consumption (MJ/year)
1	2	3	4	5	6	7	8	9 = 5 at Max Demand	10 = 5 *6*7*8
Group similar equipment with the same consumption tendencies such as lights, fans, chillers, compressors, pumps, cooling towers, heaters, lifts and escalators									

TABLE 4: BUILDING INFORMATION	
Building Description: Building Name: Address: Contact Person: Telephone: Date: Completed By:	Year First Occupied: Year Refurbished: Number of Floors Underground: Above Ground: Gross Floor Area: Nett Floor Area:
USE OF BUILDING Avg Daily Occupation Hours In Use Electrical/Mechanical Weekdays _______ to _________ Saturdays ________ to __________ Sundays _________to __________ Provision after hours:	Use Offices ☐ Shops ☐ Laboratory ☐ Residence ☐ Lectures ☐

Physical Properties				Mechanical/Electrical Systems			
Windows: % of Walls	N/NE %	E/SE %		A/C Type	Room Units		☐
	S/SW %	W/NW %			Packaged Units		☐
	Can be opened (Y/N)?				Central System VAV		☐
Glass type: Reg☐ Reflect☐ Absorb☐ Double ☐					Dual Duct System		☐
	Shadow Factor:				Fan Coil Unit		☐
Type of Shading	Overhang above Window		☐		Induction Unit		☐
	Fins next to window		☐		Other		☐
	Outside Shading		☐				
	Blinds Inside		☐	Lighting Type		Fluorescent	☐
	Outside Glass Panel		☐	Lamps per fitting			
	Other		☐	Lamp Length			
External Wall	Asbestos or Steel		☐	Incandescent	☐	Other	☐
	25 mm Insulation		☐				
	50 mm Insulation		☐	Installed Capacity			
	Concrete		☐	Lighting		Cooling	
	Brick		☐	Transformer		Heating	
	25 mm air space		☐				
	Other		☐	Temperature Required Summer		°C to	°C
External Wall Thickness:	mm Colour:			Winter		°C to	°C
Internal Wall	None		☐	Temperature Measured Summer		°C to	°C
	Light Weight		☐	Winter		°C to	°C
	Partitions		☐	Lighting Required			Lux
	Brick		☐	Measured			Lux
Thermal Mass Of Building	Light ☐ Medium ☐ Heavy ☐			Comments			

Previous Energy Management Activities:		
Has Energy Audit Been Completed :	When:	By Whom:
Were Energy Management Activities Implemented:	When:	By Whom
Description:		
Energy Management System in Use:	When	
Person Responsible:		

WALK THROUGH AUDIT **Table 5A**

Category	Situation	Specific Problem					Description/Remarks
		Leakage	Isolation	Damage	Dirt	Safety	
Building Internal Climate							
Air Circulation System							

WALK THROUGH AUDIT **Table 5B**

Category	Situation	Specific Problem					Description/Remarks
		Leakage	Isolation	Damage	Dirt	Safety	
Cooling							
Heating and Water							

WALK THROUGH AUDIT – LIGHTING TABLE 5 C							
Situation	Lighting at Working Level (Lux)		Specific Problem				Description/Remarks
	Measured	Required	Diffusers Dirty or Discoloured	Tubes Inoperative	Lights on in Unoccupied Areas	Lights on After Hours	

CALCULATION OF INDICES		TABLE 6
ENERGY INDICES	FORMULAE	UNITS
SPECIFIC ENERGY CONSUMPTION	$\frac{\text{ANNUAL ENERGY CONSUMPTION}}{\text{NET AREA}} \times \frac{\text{ACTUAL OPERATING HOURS}}{2500}$	MJ/m^2
SPECIFIC ENERGY COST	$\frac{\text{ANNUAL ENERGY COST}}{\text{NET AREA}} \times \frac{\text{ACTUAL OPERATING HOURS}}{2500}$	R/m^2
SPECIFIC MAXIMUM DEMAND	$\frac{\text{AVERAGE MAXIMUM DEMAND (kW OR kVA)}}{\text{NET AREA}}$	W/m^2 or VA/m^2
AVEARAGE ENERGY COST	$\frac{\text{ENERGY COST}}{\text{ENERGY CONSUMPTION}}$	R/MJ
ELECTRICAL MAXIMUM DEMAND RATIO	$\frac{\text{kW or kVA (SUMMER)}}{\text{kW or KVA (WINTER)}}$	None
AVERAGE ELECTRICAL LOAD FACTOR	$\frac{\text{kWh/year}}{\text{TOTAL MONTHLY MAXIMUM DEMAND X ACTUAL OPERATING HOURS}}$	None
SPECIFIC COOLING CAPACITY	$\frac{\text{kW COOLING}}{\text{NET AREA}}$	KW $Cooling/m^2$
SPECIFIC HEATING CAPACITY	$\frac{\text{kW HEATING}}{\text{NET AREA}}$	KW $Heating/m^2$

COMPONENT ENERGY CONSUMPTION		TABLE 7	
	ENERGY CONSUMPTION (MJ/YEAR)	ELECTRICAL MAXIMUM DEMAND (kVA)	
		SUMMER	WINTER
LIGHTING			
VENTILATION AIR CIRCULATION			
COOLING			
COOLING PUMPS AND COOLING TOWERS			
HEATING			
HEATING PUMPS			
DOMESTIC HOT WATER			
LIFTS AND ESCALATORS			
SMALL POWER AND PROCESS EQUIPMENT			
KITCHEN AND LAUNDRY			
COMPUTERS			
OTHER			
TOTAL			
DIFFERENCE			
TOTAL FROM ACCOUNTS			

Specific Consumption Standards

Type of Facility		Specific Energy Consumption MJ/ m^2 per annum		Specific Maximum Demand VA/ m^2	
		Low	High	Low	High
Offices	With air-conditioning	500	1800	45	120
	Without air-conditioning	300	800	25	60
Shopping Centres	With air-conditioning	700	2000	70	150
	Without air-conditioning	300	800	30	70
Hotels	With air-conditioning	1000	5000	50	120
	Without air-conditioning	500	750	25	75
Hostels and Residences		200	500	25	60

Correction Factors

a.) Operating hour: Standard operating hours per annum for office buildings are taken as 2500 hours. Actual operating hours are estimated on an area-weighted basis eg. If 90 % of the nett floor area of a building is occupied 10 hours a day for 250 days a year and the remaining 10 % of the area is continuously occupied, then the operating hours are:

(9 x 250 x 10) + (0.1 x 365 x 24) = 3 126 hours

Therefore the appropriate correction factor is 3126 / 2500 = 1,25. This factor can be multiplied by the norm shown above to get an adjusted norm for the particular building.

b.) Further correction factors may be developed where internal heat generation is significant due to equipment (eg. Computers) or to population density and activity rate of occupants.

Appendix C

Results of Audit and Tariff Details

Appendix C

Overview of Tariff Structures

Examples of some tariffs that are available to consumers in South Africa are given below: [5]

- **Fixed charge (Flat rate)** is a fixed payment made per month independent of consumption.
- **Single Energy Rate** is a payment made for consumption only at a fixed rate. Typically applied to residential consumers.
- **Inclining Block Rate** consists of different prices for different energy usage. For example, a lower block rate for the first 1000 units of consumption and a high block rate for the balance of consumption.
- **Declining Block Rate** is the reverse of the inclining block rate whereby a higher initial rate is charged and a lower rate for the balance of consumption.
- **Demand Tariff** consists of a maximum demand charge and an energy rate.
- **Time-Of-Use (TOU) Tariffs** apply different rates are applied at different times of the day and for different seasons (high and low demand periods).
- **Real-time Pricing (RTP)** is when the energy price changes in real time (e.g. on an hourly basis).
- **Curtailment Agreements** where a customer gets a rebate for switching off load during periods when the utility's peak occurs or when the utility specifies.

The electric rate structures vary greatly from utility to utility, but they all have common features. Commercial and industrial customers have three to four major components to their electricity bill. These are: [54]

- **Customer cost:** A basic charge is levied on certain customers. A connection fee is payable by new customers in order to contribute to the cost of the additional connections or basic charge
- **Energy Cost** normally a c/kWh charge
- **Demand Cost** either a R/kW or R/kVA charge
- **Service Charges** are designed to recover a share of the cost incurred irrespective of there being any consumption eg. Billing, meter reading, running costs, administration costs etc. This charge is normally applied as a percentage of the energy cost or demand cost or the total usage cost. Typical examples of these charges within the South African Electricity Supply Industry (ESI) and its confines are given below: [55]

- **Voltage surcharge:** Calculated as a percentage of demand and active energy charges. The greater the voltage at which the consumer's supply's transformer connects with the supply grid at, the lower the surcharge. This surcharge contributes to the maintenance costs of the utility and the energy losses in transformers.
- **Transmission surcharge:** Calculated as a percentage of the demand, active and reactive energy charges after the voltage surcharge has been levied.
- **Circuit Breaker Fee,** a fixed fee proportional to the size of a customer's circuit breaker. Usually, the greater the rating on the circuit breaker, the higher the fee payable.
- **Technical Losses** – typically calculated at 3% of the active energy cost for that month. [55]
- **Distribution Surcharge** - typically calculated at 2% of the active energy cost for that month.

4.1.1.1. Conventional and General Tariff Terms as applied to Bulk Supply Agreement Tariffs

There are numerous terms that are applied to tariff agreements. To list all of these here would be an onerous task that will detract from the task at hand. These terms and their definitions can be easily accessed from the numerous texts available. [55] To assist with the understanding of the subsequent analysis, the following definitions are deemed necessary.

- **Kilowatt-hour:** An electrical energy unit of measure equal to 1 kilowatt of power supplied to, or taken from, an electric circuit steadily for 1 hour.
- **Energy:** Measured in kWh during Peak, Standard and Off-Peak periods during the days of the month.
- **Maximum Demand:** The highest half-hourly integrated demand in kVA or kW taken by the customer at any time of the month. Measured during peak or standard periods in the month.
- **Peak, Standard and Off-Peak Periods:** The different times during the day as shown in figure 4.2, during which varying energy charges apply.
- **Notified Maximum Demand:** The notified maximum demand, notified in writing by the customer, gives the utility an indication of what the customer's demand requirements will be for that year.
- **The Notified Minimum Demand** is the minimum demand charge that the utility will charge a customer for any billing month. The Notified Maximum Demand is used for

calculating this minimum demand charge. This charge is calculated as 70% of the Notified Maximum Demand. [54] For example a customer has a notified maximum demand of 5000 kW and a notified minimum demand of 3500 kW which is obtained as a result of a specified 70% of maximum (i.e. 5000 x 70%). In this example, if the customer has a maximum demand that is less than the notified minimum demand (3500 kW), then this customer will be charged for the notified minimum demand. This encourages customers to maintain a good load factor.

4.1.1.2. Structure of Durban Municipality's Time-Of-Use (TOU) Tariff

Durban Electricity (DE) is the largest electric utility in South Africa. Prior to 1 January 2003, their Time-Of-Use tariff structure was very similar in nature to Eskom's time-based tariff called MegaFlex. The major difference between these two tariffs was that DE's TOU tariff had two demand charges whereas Eskom had just one demand charge. [54]

Eskom's Mega-Flex tariff demand charge is as follows: [55]

- Maximum Demand Charge - Payable for each **kW** of the **maximum chargeable demand** supplied during the month measured over **30 minutes integrating periods,** payable in peak or standard periods on weekdays and Saturdays. No demand charge is applicable during the off-peak periods.

DE's two demand charges were as follows:

- **Maximum Demand Charge -** Measured during **Peak** and **Standard** periods only. Calculated in kVA
- **Overall Maximum Demand -** Measured during **all** periods. This demand charge was in addition to the maximum demand charge mentioned above.

The aim of the overall maximum demand charge was to encourage bulk customers to have a load factor as close as possible to one.

In line with the NER's policy of having cost reflective tariff structures, this tariff has now been changed from the 1 January 2003 to be more in line with Eskom's Mega-Flex tariff and therefore there is now only one demand charge, namely the Maximum Demand Charge.

For the purpose of all subsequent financial calculations, the Time-Of-Use (TOU) tariff post 1 January 2003 will be used to calculate possible savings. Some of the historical costs will obviously be based on the older tariff structure. The amendment to this tariff will not have much bearing on the analysis since the overall maximum demand and the maximum demand always occurred at the same time.

Durban Electricity TOU Tariff Structure prior to 1 January 2003

Maximum Demand Charge (R/kVA)	Measured during **Peak** and **Standard** periods only **High Demand** R14.1362 + VAT = **R16.1153/kVA** **Low Demand** R12.7368 + VAT = **R 14.5200/kVA**
Active Energy Charge (c/kWh)	**High Demand** (June, July, August) **Peak** 35.0387 + VAT = **39.9441 cents/kWh** **Standard** 14.6374 + VAT = **16.6866 cents/kWh** **Off-Peak** 8.4004 + VAT = **9.5765 cents/kWh** **Low Demand** (September to May) **Peak** 23.5114 + VAT = **26.8030 cents/kWh** **Standard** 13.1587 + VAT = **15.0009 cents/kWh** **Off-Peak** 8.0360 + VAT = **9.1610 cents/kWh**
Overall Maximum Demand Charge (R/kVA)	Measured during **all** periods. *(In addition to Maximum Demand Charge)* R19.5280 + VAT = **R22.2537/kVA**

Fig: 4.1. Durban Electricity TOU Tariff Structure prior to 1 January 2003

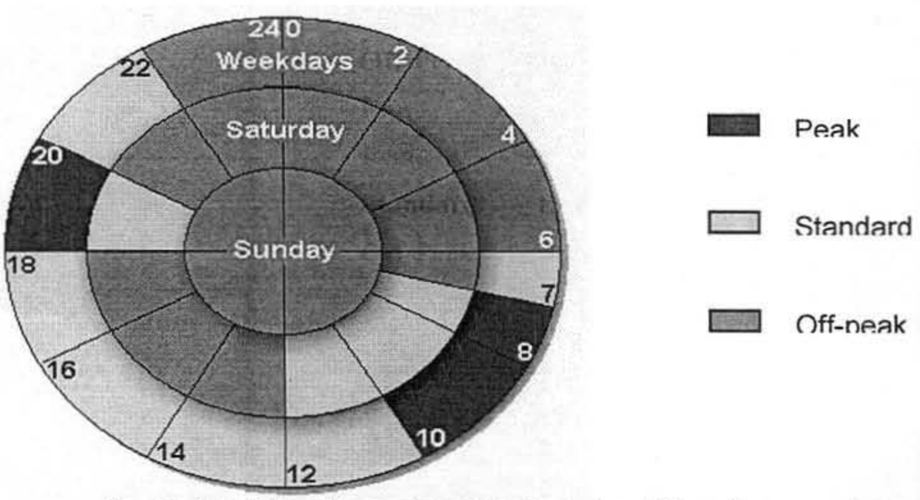
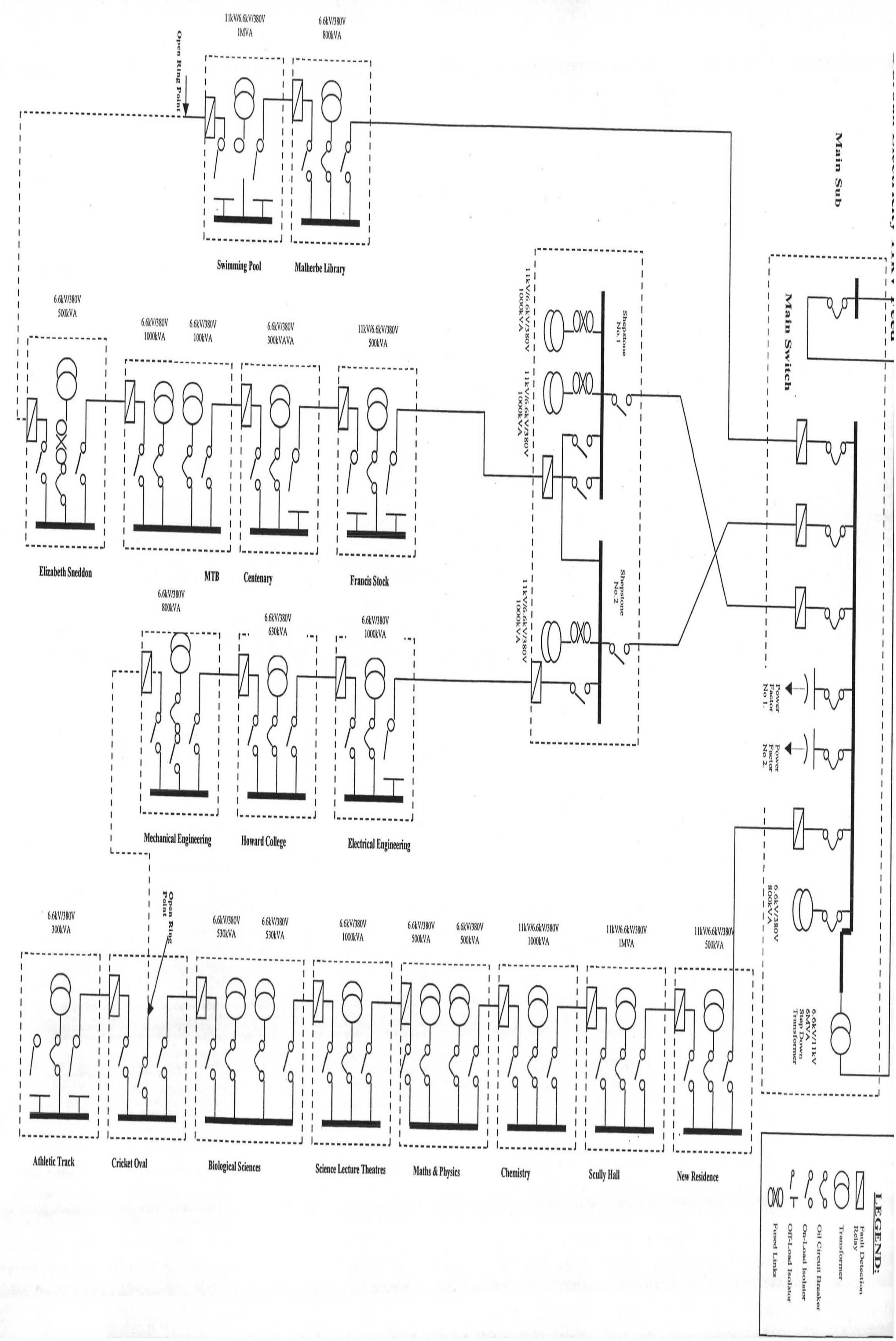


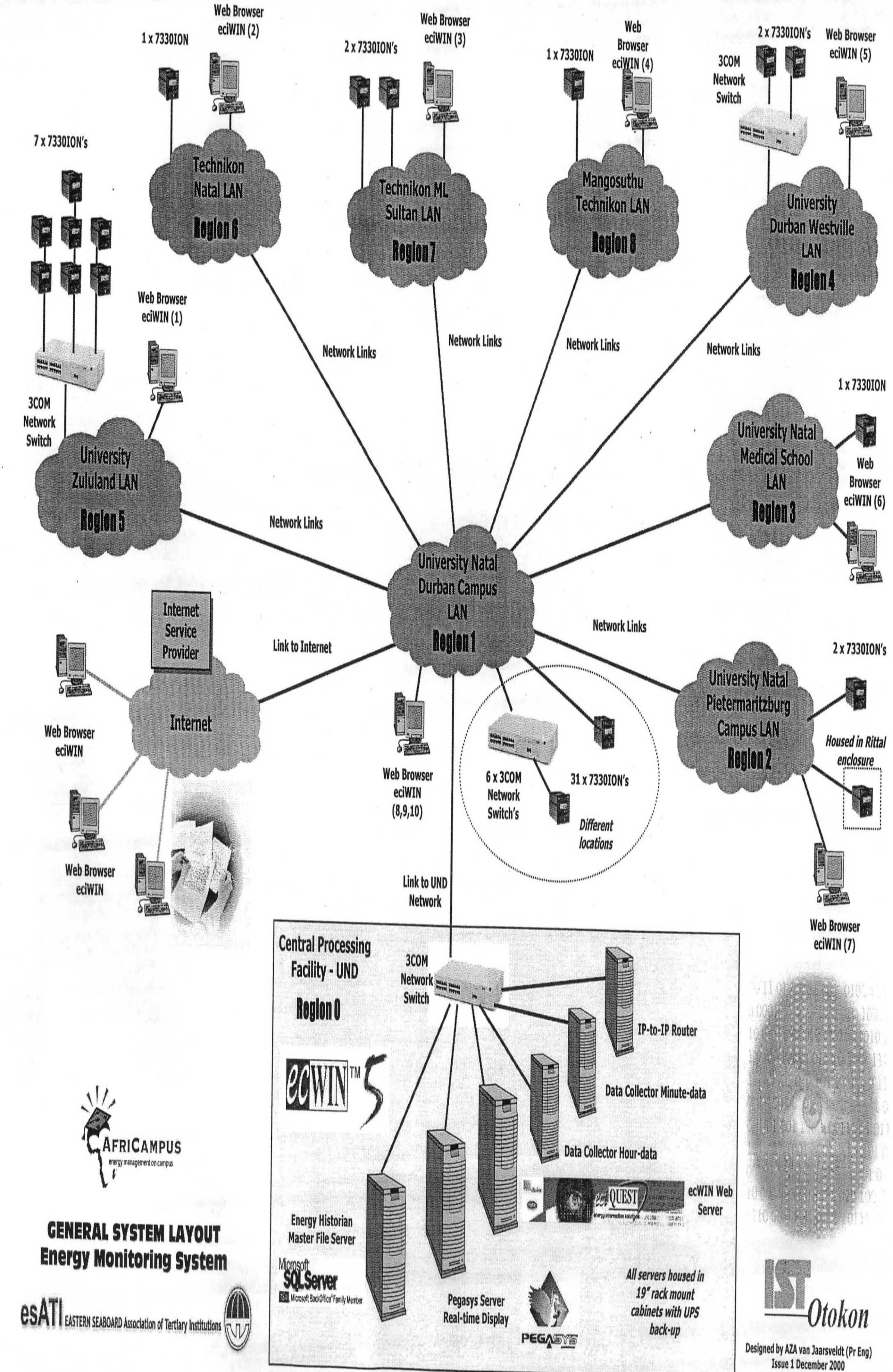
Fig: 4.2. The different time periods of the day during which varying energy charges apply.

Durban Electricity TOU Tariff Structure post 1 January 2003

Maximum Demand Charge (R/kVA)	Measured during **Peak** and **Standard** periods only **High Demand** R 34.4736 + VAT = **R 39.2999/kVA** **Low Demand** R 34.4736 + VAT = **R 39.2999/kVA**
Active Energy Charge (c/kWh)	**High Demand** (June, July, August) **Peak** 35.0387 + VAT = **39.9441 cents/kWh** **Standard** 14.6374 + VAT = **16.6866 cents/kWh** **Off-Peak** 8.4004 + VAT = **9.5765 cents/kWh** **Low Demand** (September to May) **Peak** 23.5114 + VAT = **26.8030 cents/kWh** **Standard** 13.1587 + VAT = **15.0009 cents/kWh** **Off-Peak** 8.0360 + VAT = **9.1610 cents/kWh**
Transmission Surcharge	**1%**
Technical Losses	**3%**
Voltage Surcharge	**VOLTAGE** / **SURCHARGE (%)** **275 kV** — **0.00** **132 kV** — **2.25** **33 kV** — **3.00** **11 kV** — **10.50** **6.6 kV** — **12.75** **400 V** — **22.50**
Distribution Surcharge	**2.00%**



Main Sub
Main Switch
Open Ring Point
11kV/6.6kV/380V 1MVA
6.6kV/380V 800kVA
Swimming Pool
Malherbe Library
6.6kV/380V 500kVA
6.6kV/380V 1000kVA
6.6kV/380V 100kVA
6.6kV/380V 300kVAVA
11kV/6.6kV/380V 500kVA
Elizabeth Sneddon
MTB
Centenary
Francis Stock
Shepstone No. 1
11kV/6.6kV/380V 1000kVA
11kV/6.6kV/380V 1000kVA
Shepstone No. 2
11kV/6.6kV/380V 1000kVA
6.6kV/380V 800kVA
6.6kV/380V 630kVA
6.6kV/380V 1000kVA
Mechanical Engineering
Howard College
Electrical Engineering
Power Factor No 1.
Power Factor No 2.
6.6kV/380V 800kVA
6.6kV/11kV 6MVA Step Down Transformer
Open Ring Point
6.6kV/380V 300kVA
6.6kV/380V 530kVA
6.6kV/380V 530kVA
6.6kV/380V 1000kVA
6.6kV/380V 500kVA
6.6kV/380V 500kVA
11kV/6.6kV/380V 1000kVA
11kV/6.6kV/380V 1MVA
11kV/6.6kV/380V 500kVA
Athletic Track
Cricket Oval
Biological Sciences
Science Lecture Theatres
Maths & Physics
Chemistry
Scully Hall
New Residence
LEGEND:
Fault Detection Relay
Transformer
Oil Circuit Breaker
On-Load Isolator
Off-Load Isolator
Fused Links



1 x 7330ION
Web Browser eciWIN (2)
2 x 7330ION's
Web Browser eciWIN (3)
1 x 7330ION
Web Browser eciWIN (4)
2 x 7330ION's
Web Browser eciWIN (5)
3COM Network Switch
7 x 7330ION's
Technikon Natal LAN Region 6
Technikon ML Sultan LAN Region 7
Mangosuthu Technikon LAN Region 8
University Durban Westville LAN Region 4
Web Browser eciWIN (1)
Network Links
Network Links
Network Links
Network Links
1 x 7330ION
3COM Network Switch
University Zululand LAN Region 5
University Natal Medical School LAN Region 3
Web Browser eciWIN (6)
Network Links
University Natal Durban Campus LAN Region 1
Internet Service Provider
Link to Internet
Network Links
2 x 7330ION's
Internet
Web Browser eciWIN
University Natal Pietermaritzburg Campus LAN Region 2
Housed in Rittal enclosure
Web Browser eciWIN (8,9,10)
6 x 3COM Network Switch's
31 x 7330ION's
Different locations
Web Browser eciWIN
Link to UND Network
Web Browser eciWIN (7)
Central Processing Facility - UND
Region 0
3COM Network Switch
IP-to-IP Router
ecWIN™ 5
Data Collector Minute-data
Data Collector Hour-data
eciQUEST
ecWIN Web Server
Energy Historian Master File Server
Microsoft SQLServer
Microsoft BackOffice Family Member
Pegasys Server Real-time Display
PEGASYS
All servers housed in 19" rack mount cabinets with UPS back-up
AFRICAMPUS
energy management on campus
GENERAL SYSTEM LAYOUT
Energy Monitoring System
esATI EASTERN SEABOARD Association of Tertiary Institutions
IST Otokon
Designed by AZA van Jaarsveldt (Pr Eng)
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